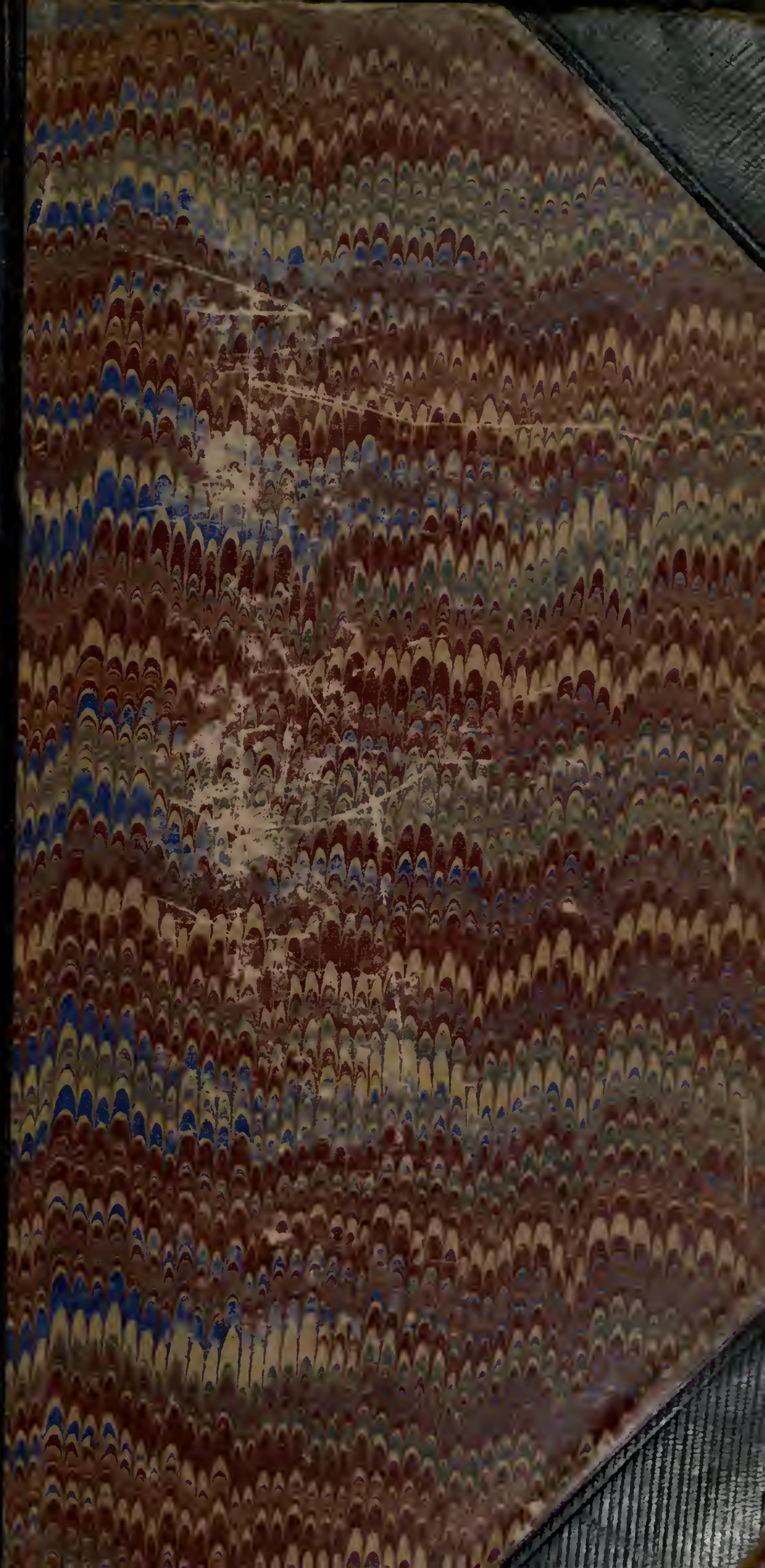

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Department of Agriculture, Forestry Division

Bulletin

1 Report on the relation of railroads to forest supplies and forestry: Together with Appendices on the structure of some timber ties, etc.,

2 Report on the forest conditions of the Rocky Mountains, and other papers; with a map showing the location of forest areas on the Rocky Mountain range, second edition.

3 Preliminary report on the use of metal track on railways as a substitute for wooden ties by E.E.Russell Tratman, to which is added a report of experiments in wood seasoning by the Chicago, Burlington and Quincy Railroad and other notes.

4 Report on the substitution of metal for wood in railroad ties, by E.E.Russell Tratman, with a discussion on practicable economies in the use of wood for railway purposes, by B.E.Fernow

5 What is forestry? by B. E. Fernow.

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DEPARTMENT OF AGRICULTURE.
FORESTRY DIVISION.
BULLETIN No. 1.‸5

REPORT

ON THE

RELATION OF RAILROADS TO FOREST SUPPLIES AND FORESTRY:

TOGETHER WITH

APPENDICES

ON THE

STRUCTURE OF SOME TIMBER TIES, THEIR BEHAVIOR, AND THE CAUSE OF THEIR DECAY IN THE ROAD-BED; ON WOOD PRESERVATION; ON METAL TIES; AND ON THE USE OF SPARK ARRESTERS.

COMPILED BY THE CHIEF OF THE FORESTRY DIVISION.

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LETTER OF TRANSMITTAL.

FORESTRY DIVISION, DEPARTMENT OF AGRICULTURE,
Washington, D. C., May 30, 1887.

SIR : I have the honor to submit for publication as a special bulletin, prepared under your instructions, a collection of reports, illustrating the Relation of our Railroads to Forest Supplies and Forestry, and pointing out on a practical basis how an economy in the use of forest supplies by the railroads can be effected.

Respectfully,

B. E. FERNOW,
Chief of Forestry Division.

Hon. NORMAN J. COLMAN,
Commissioner.

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FACULTY
OF
FORESTRY

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INTRODUCTORY.

The following Reports, written mostly by experts, form a more or less exhaustive account of what the railroads of our country have done or are doing to deplete our forests, and show how the wastefulness in the use of material, which is in danger of great diminution if not exhaustion, may be checked, to some extent, by increasing its durability through the employment of preserving processes; by substituting, where admissible on financial grounds, other material; by observing conditions in its use hitherto largely overlooked; and, lastly, by insuring a continuance of supply through active forestry work on the part of railroad companies and in other ways.

Considering the wasteful manner of getting out railroad timber, it can be fairly estimated that to build our present railroad system more than one hundred million acres, or one-fifth of our present forest area, were stripped during the last fifty years, and the next fifty will very likely call for more than double that amount, judging from the accelerated development which is probable and the requirements for renewal.

While railroads have done much for the growth and development of our country, they are also responsible for much of the hindrance to reform in the use of our forest resources. The rapid extension of our railroad system has brought within reach of markets distant forest areas, where, to make lumbering profitable in the absence of home consumption for the inferior grades of material and leavings, wasteful and destructive methods of utilization have to be employed.

While, therefore, directly and indirectly, railroad enterprises have contributed largely to a considerable reduction (if not destruction) of forest supplies, it might be presumed that, depending as they do on these supplies and being by their own continuous character most deeply concerned in their continuation, the railway companies would feel a special interest in forest preservation.

With this view the following reports have been prepared as aids to a proper appreciation of our wood material and its economical use.

The report of Mr. M. G. Kern has been written after much correspondence with railroad managers. Extracts from this correspondence are appended, with the design of showing whatever objections have been raised to the practicability of railroad companies engaging in active forestry.

I would call particular attention to the original work of Mr. P. H. Dudley, the study of which will prepare one for a more critical estimate of the processes employed for wood preservation, so ably presented by Col. Henry Flad, to which also some notes have been appended taken from a paper kindly prepared by Mr. Howard Constable, C. E. These papers are intended to appeal and give information to the business or unprofessional man who may be interested in the subject, and who is frequently the motive power of operations conducted by professional men. It should be added, that while it has been the custom to describe the different processes of wood preservation, coupling each with the use of certain antiseptics, or, *vice versa*, to speak of antiseptics as necessitating the employment of certain processes; and though in the main Colonel Flad has followed this customary treatment of the subject there is no good reason for continuing such strict classification: the practical man will observe the practical expedients of all the processes and select and combine them to meet the requirements of his special case, cutting away from the hampering influence of mere precedent, and adopting the best means to an end, thus carrying out what Mr. Constable is pleased to call the "American idea of wood-preserving processes."

In connection with these papers I would also refer the reader to a very valuable report on wood-preservation made by a committee of the American Society of Civil Engineers to that body at its annual convention in June, 1885.

A new interest in the line of wood-preserving processes has been added in the economical applications of wood-creosote oil, made from the Southern pine, a report on which was kindly prepared by Capt Wm. H. Bixby, U. S. A.

Particular attention is called to the reference table for comparing annual charges, prepared by the writer, which does away with all cumbersome calculations hitherto practiced even by engineers.

The notes on metal ties, prepared in this office, though perhaps not exhaustive, will furnish nevertheless ready references for the use of engineers, and give cumulative evidence of the practicability and desirableness of this substitute for wooden ties. While the treatment of this subject from the railroad engineer's point of view may seem at first sight not germane to the work of the Forestry Division, I think it cannot be denied that forest preservation must be indirectly but most effectively and practically promoted among this class of consumers by just such a presentation of the experiences, so far had, with a substitute for what involves one of the most wasteful and destructive uses of our forest resources.

With the improvement which has been made in the laws and in their execution, regarding fires set by locomotives, providing a more ready method for the collection of damages, the use of spark arresters has been considerably extended, and the two papers on the subject of this means of preventing fires, prepared by well-known railroad engineers, and prefaced by Mr. N. H. Egleston, it is hoped, may weigh sufficiently with companies not yet provided with those contrivances to induce their adoption in order to avoid one cause of useless forest devastation.

B. E. F.

FACULTY
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THE RELATION OF RAILROADS TO FOREST SUPPLIES AND FORESTRY.

By M. G. Kern, *Agent of the Department.*

A discussion of the relation of the railways to the forests of America may be preceded appropriately by a glance at the origin and growth of the railroad system.

The year 1825 will be always memorable in American history for the completion of the first great work of internal improvement in the United States, the Erie Canal, constituting a navigable water-way between the Hudson River and Lake Erie, through which the vast territory tributary to the Northern Lakes was opened to the commerce of the world by a channel far more advantageous to American interests than that offered by the Saint Lawrence River.

The completion of this work decided forthwith the question of supremacy amongst Atlantic seaports, and to New York harbor henceforth the products of the newly-opened empire of agriculture and production floated to find their outlets into the world's commerce.

Aroused to unprecedented exertion to counterbalance the advantages gained by New York, the commercial and shipping interests concentrated around Chesapeake Bay united in undertaking a railway to connect the tide-water of the bay with the Ohio River, necessitating the passage of the Allegheny Mountains, which was quite impracticable by means of a canal.

On July 4, 1828, the citizens of Baltimore assembled to break ground for the inauguration of this work, the magnitude of which, and its electrifying influence on the entire country, could not be fully foreseen on that memorable day.

In 1830 the Baltimore and Ohio Railway, in the earliest stage of its growth, extended 23 miles west of the city of Baltimore, and was operated for the first two years by horse-power.

The invention of the locomotive, following soon afterward, gave the impetus which brought into existence the giant railway system, to which is due, in great measure, the rapid commercial, social, and political development of the North American continent.

The new system of transportation, as well as new inventions in the construction of the railway track, rolling-stock, and machinery were rapidly adopted, so that in a few years the principal Atlantic States were in railroad communication with each other.

The increase of railway mileage from 1830 to 1840 was 2,795 miles, and the mileage of 1850 was reported as 9,021 miles.

LAND-GRANT ROADS.

Up to this time the railways were constructed and equipped by the people, unaided by the Government, State or Federal; but in consideration of the benefit accruing from them to the country at large, and desiring to extend these motors of civilization over the young and sparsely-settled States of the Union, Congress adopted a new policy, of momentous importance to the internal improvements of the Union. The year 1850, therefore, on account of this precedent established by Congress, may be regarded as the second epoch in the construction of the railways of the United States.*

Although at first the grants were made to the several States, they were in all cases transferred as speedily as possible to railroad companies which were chartered by them to construct the lines upon the general route specified in the act of Congress by which the lands were granted.

The enormous increase of mileage constructed during the ensuing decade speaks eloquently, not merely for the object aimed at by Congress in making so magnificent a grant from the public domain, but likewise of the indefatigable energy of the American people.

The mileage of railways in 1860 was 30,635 miles, being an increase over 1850 of 21,614 miles. In the decade from 1860 to 1870, embracing the turbulent time of the civil war and its consequences, the question of railway construction assumed of necessity an aspect different from that of a time of peace and prosperity. In order to strengthen the integrity of the Union, Congress determined upon the construction of a system of railways connecting the Atlantic and Pacific States, making, however, the grants and concessions necessary for the consummation of so grand a project, not to the several States but to corporations organized directly for this purpose.

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* "In the case of the Illinois Central and Mobile and Ohio Railroads it granted to States in aid of railroad construction, upon specified routes, six sections of public lands of 640 acres each, for every mile of road built, to be taken by the odd numbers within 6 miles of the proposed route, provision being made that under certain circumstances the grant may be enlarged to apply to odd sections within 15 miles on either side, so as to make up the full amount intended to be granted. Many of the grants were subsequently further enlarged to apply to sections of odd numbers within 20 miles of the line. Upon the sections of public land of even numbers within the limits of the grant the price was raised from $1.25 to $2.50 per acre."—(Poor's Manual of the Railroads, 1876.)

The construction of the Pacific railways and their connecting links, vigorously pursued during this decade, naturally swelled the increase to a great extent; much activity in construction was necessary also to rebuild and to enlarge the systems of the Southern States, greatly damaged by the chances of the war.

The mileage in 1870 was 52,914 miles; an increase over 1860 of 22,279.

The mileage in 1880 was 93,349.

The mileage at the close of 1886 was 137,615.

From reports which have been received by the publishers of Poor's Manual of Railroads in regard to work done or in progress, it is evident that, unless some serious convulsion should appear to disarrange and defeat plans, not less than 12,000 miles of new road will be constructed during the present year, so that at the close of 1887 we shall have 150,000 miles of road or 187,000 miles of railway track.

The public lands have been granted in aid of seventy-eight railroads, the first grant having been made in 1850 to the States of Illinois, Alabama, and Mississippi, for the purpose of aiding the construction of the Illinois Central and the Mobile and Ohio River roads, making a continuous line of railway from Chicago to Mobile. The granting of land directly to railroad companies rather than to States for the benefit of railroads, began with the grant to the Union Pacific Company in 1862.

The grants made to all the roads are estimated by the Commissioner of Public Lands to involve 197,203,808 acres, being only 5,000,000 acres less than the entire area of the thirteen States which originally composed the Union. Of this vast amount of land there had been certified or patented to the aided railroads, up to the 7th of March of the present year (1887), 49,178,877 acres, and at the close of the last fiscal year (1886) selections of land by the companies amounting to 16,571,300 acres in addition were awaiting examination and the decision of the proper officers of the Government. Of the land-grant roads there were completed on the 30th of June, 1886, as appears on the books of the General Land Office, 17,724 miles, distributed in the States and Territories as follows:

States.	Miles.	States.	Miles.	States.	Miles.
Alabama	901.43	Indiana	241.35	Nebraska	768.52
Arkansas	602.24	Iowa	1,547.64	Nevada	446.00
Arizona	383.00	Kansas	1,485.65	New Mexico	167.00
California	1,037.91	Louisiana	530.00	Oregon	325.80
Colorado	208.60	Michigan	1,045.01	Utah	225.00
Dakota	410.98	Minnesota	2,144.11	Washington	463.60
Florida	639.97	Mississippi	384.00	Wisconsin	973.50
Idaho	90.00	Missouri	625.75	Wyoming	500.00
Illinois	707.00	Montana	780.00		
				Total	*17,724.06

In many cases the roads aided have received new names since the grants were made to them or they have lost their names by being merged in other roads, so that their original names do not appear in our ordinary lists of roads. In some cases projected roads to which lands were granted have been abandoned, and consequently the grants have lapsed. In other cases claims to large amounts of land have been rendered invalid because of the failure to complete the roads within the time stipulated in the grants, and the question of the forfeiture of this land is now awaiting decision.—N. H. E.

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* Later information from the Commissioner of Railroads shows that on the 1st of May, 1887, the length of the land-grant roads, completed and in operation, had increased to 17,978 miles.

GEOGRAPHICAL RELATION OF RAILROADS TO THE FOREST AREA.

With the railway map of to-day before us, a brief consideration may properly be given to the physical characteristics of the country in reference to the distribution of the forests, from which the most indispensable material of construction has to be drawn. The vast area of country lying east of the Rocky Mountains presents the two opposite extremes of forest and treeless plain.

The States bordering on the Atlantic coast from north to south, together with the interior and Middle States, are forest territory, in which settlement and civilization could gain a foothold only by the use of the ax. The forest extended from the Northern Lakes to the Gulf of Mexico, but midway in the Mississippi Valley was met by the treeless prairie. The change, however, was not abrupt, but gradual, both forest and prairie dovetailing deeply into each other. The middle ground, extending from Minnesota to Texas, is a territory peculiarly favored by the hand of nature, possessing the fertility and ease of culture of a prairie, together with an abundance of timber and protection from the inclemencies of the climate of the plains of the West, on which trees flourish only along the water-courses.

On the Pacific slope the greatest forest area is again found in the North, extending in many ramifications through the mountain ranges. The area of treeless territory, however, is equally large, especially in the southern half of this section.

At the time when the railways were undertaken, it is evident that an abundance of material for construction existed throughout the timbered district, and that no real value was placed on the material, which, though indispensable, was everywhere encumbering the ground. In the construction of roads over widely-extended treeless plains, the supply had of necessity to be brought from great distances at a corresponding cost.

Considering the stupendous amounts of timber already withdrawn from native forests, the annual demands of railways now in operation, and the increase of mileage from year to year, it becomes necessary to take a more accurate survey of the fields of demand and supply, unbiased by the popular delusion of the inexhaustible forest wealth of America. This necessity is no longer either to be ignored or lightly treated as in the past.

DEMANDS OF THE RAILWAY SYSTEM.

For construction.—Assuming 187,500 miles of track * in the United States, and taking 2,640 ties for each mile, the number of ties in use would be 495,000,000, each tie containing an average of 3 cubic feet;

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* In considering the relation of the railways to the forests, it is important to bear in mind the distinction between the length of *road* and the length of *track*. These often differ greatly from each other. For example, the length of the New York

the amount of timber imbedded under the entire mileage and undergoing a constant process of decay is, therefore, 1,485,000,000 cubic feet.

Bridge- and trestle-work, timber and poles for piling, cannot be estimated with the same accuracy, as roads vary indefinitely in topography and material of bridge construction in use, whether wooden or iron, piling or stone masonry. As a rule, wooden structures are employed in the first stage of construction of new roads, to be replaced as soon as practicable by more permanent material. The roads of the older States are, therefore, more substantially built than a majority of southern and western roads, in which a far greater percentage of timber is employed in construction than on the great trunk lines of the Eastern and Middle States. On many southern roads, running through low and swampy districts, piling is used to a great extent, but accurate figures cannot be given as to the timber used for this purpose. An average of 2,000 cubic feet per mile is considered approximately correct by engineers consulted on this subject.* Therefore, 187,500 miles of track contain 375,000,000 cubic feet of bridge and trestle timber.

As with the preceding items of bridge and trestle construction, it is alike impossible to make a correct estimate as to the quantity of timber used per mile for station-houses, buildings for all purposes, and platforms, all requiring large amounts of timber. The amount of timber used in track construction proper is, therefore,—

	Cubic feet.
Ties for 187,500 miles	1, 485, 000, 000
Bridge and trestle timber	375, 000, 000
Total	1, 860, 000, 000

It can be safely assumed that for every cubic foot ready for use, 1⅔ cubic feet of round timber is required.† Therefore the amount of round timber

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Central and Hudson River Railroad is 442 miles; but it has four tracks from Albany to Buffalo, besides 551 miles of sidings, making in all 2,043 miles of track to be furnished with ties, bridge timber, etc. So the length of the Pennsylvania road from Jersey City to Pittsburgh is 445 miles; but the road having a double track throughout and 449 miles of siding, the whole length of the track to be supplied with ties, &c., is 1,339 miles. A careful comparison of the length of roads and the length of their tracks, so far as the latter are reported, warrants the conclusion that 25 per cent. should be added to the reported length of our railroads as a whole in order to represent fairly the additional demand for rails, ties, etc., made by double tracks and sidings, or turn-outs.—N. H. E.

*The Chicago, Saint Paul, Minneapolis and Omaha Company report their timber-work for piling, trestles, bridges, and culverts on 1,600 miles of road as being 1 foot to every cubic yard of earth-work. Earth-work on 1,600 miles amounts to 15,000 cubic yards per mile. Two per cent. of its entire length is in bridges of all kinds. The average duration of wooden culverts and pile and trestle bridges was eight to ten years; of truss-bridges, nine to eleven years.

†That the allowance here made for the waste of the forests in preparing ties or other timber for market is fully warranted, and the waste often much larger, may be seen from the following extract from a trustworthy lumber journal:

"There is no branch of the lumber industries where there is more waste of raw material than in making ties. Each tie is split from clear wood, and it takes about necessary to yield the above product may be estimated at 3,100,000,000 cubic feet.

Telegraph Poles.—Each mile of railway requiring thirty telegraph poles, the total number of poles in use on 137,615 miles of railway at the close of 1886 was 4,128,450, and, making due allowance for double rows along many sections of road, can be safely estimated at 5,000,000, with an average content of 10 cubic feet each, amounting to 50,000,000 cubic feet of pole timber.

In consideration of the steady increase of mileage during the last decade, it is is safe to anticipate a yearly addition of 5,000 miles of track, creating annually an additional demand for 13,200,000 ties, and 10,000,000 cubic feet of bridge and trestle timber, together with corresponding amounts of construction timber and telegraph poles.

To this may appropriately be added a very large amount, incapable of exact estimate, used in fencing the roads, together with timber incidentally employed for track construction.

The above figures, though they may be in certain points more or less exact, give, nevertheless, an approximate idea of the amount of timber cut for the construction of the American railway system; an amount obtainable only on a continent supplied more lavishly with forest wealth than any other portion of the globe.

Maintenance.—While no general rule can be laid down as to the lasting quality of timber imbedded under the track and used in bridges and trestle-work, subject, as it is, to the endless variety of conditions of soil and climate in different sections of the country, nevertheless it may be safely assumed that seven years is the limit of the average usefulness of ties of the best kinds of hard-wood and four years for those of the soft-woods.

Bridge and trestle timber and telegraph poles may be assumed to last ten years.

Therefore, the seventh part of 495,000,000 ties, in round numbers equal to 70,714,286, is required each year for the maintenance of a safe

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35 feet of clear lumber to make a merchantable tie. Redwood will average about 50 per centum of clear and suitable wood for ties. When to this is added the percentage of 'culls' that are arbitrarily rejected by the inspectors on behalf of the railroads at the owner's expense, it will be found that each tie represents about 75 feet of good merchantable lumber in the standing timber destroyed for it. Placing the market price of the Redwood lumber at $25 per 1,000 feet, each tie represents $1.87½ worth of lumber. In the light of these figures, it conclusively appears that the present ruling rate of Redwood railroad ties (35 cents) is grossly inadequate. The remedy lies with the owners of the lands from which the ties are cut. If they will combine, and agree that they will no longer sacrifice their timber and their work as they have been doing, but will insist on being paid at least as much approximately as the lumber represented by the ties is worth, they can control the situation. It would be far better for them to sell their lands at a small profit, and get into some more profitable occupation, than to go on for years, and at the end find themselves without either timber or money to compensate them for their wasted endeavors. The railroads must have the ties, and land-owners are foolish if they do not compel the payment of a fair price for them."—B. E. F.

track, together with one-tenth of the timber used in bridges, trestles, and pilings, and of telegraph poles in use along railroads, giving the following figures:

	Cubic feet.
70,714,286 ties (at 3 cubic feet each), equal	212, 142, 858
Bridge and trestle timber	37, 500, 000
Telegraph poles, 500,000	5, 000, 000
Total demand for maintenance	254, 642, 858

To this must be added the amount of material required for the construction of new roads, assumed above at 5,000 miles annually, being:

	Cubic feet.
13,200,000 ties	39, 600, 000
Bridge and trestle timber	10, 000, 000
150,000 telegraph poles	1, 500, 000
Total	51, 100, 000

Demands for maintenance	254, 642, 858
Demands for new construction	51, 100, 000
Total	305, 712, 858

which may safely be considered as equal to 509,521,430 cubic feet of round timber.

This amount of timber, required for the specific purposes mentioned above, is cut principally in those sections of the wooded area of the United States where the kinds of trees demanded are most abundant, and where facilities for transportation encourage their felling. Heavily wooded districts, remote from existing lines of communication, have thus far escaped the attack of the relentless woodman's ax, and form a reserve for future years, when new railway lines will extend into the dark shades of these forests to carry off the timber wealth still remaining in many sections of the land. In many of the older and more populous States of the Union the forests are already thin and meager, and many tracts reported as forest lands are simply wastes of brush and fire-wood.

Amidst the endless diversity in the location of forests and the prevalence of various kinds of timber, it is impossible to estimate with accuracy the area necessary for the production from year to year of the great amount of timber required by the railways. Estimates, to be worth more than guesses, must be based on established data, which unfortunately are but few in the forestry practice of the United States.

The number of ties obtainable from an acre of forest land is very variable. The same is true of the yield of timber on pine and cypress lands, from which are mainly derived the timbers of large dimensions for bridge construction. Trees suitable for telegraph poles are indigenous only in certain few regions, but the number of poles cut on many an acre is quite often very large.

Assuming an average yield of 300 ties per acre, 70,714,286 ties, the number demanded annually for maintenance of the present mileage of track, would require a forest area of 235,714 acres, and 5,000 miles of new road annually built would require an area of 44,000 acres to be cut over for railroad construction, in all amounting to 2,797,140 acres in one decade alone. Although 300 ties per acre may be considered too high an average for a large portion of the forests of the United States, which have been culled for the best tie-timber for many years past, yet it can be readily seen that with a smaller average per acre, a much greater area will necessarily be cut over each year. If the frequent estimate of 100 ties per acre be taken, the area drawn upon annually will be 839,142 acres, and the necessary reserve for ten years will be 8,391,420 acres.

On the other hand, assuming an average yield per acre of 3,000 cubic feet of "dimension" timber and lumber, together with 500 telegraph poles per acre, the area needed for yearly maintenance will be, for,—

	Acres.
"Dimension" timber and lumber	12,500
Telegraph poles	1,000
	13,500
And adding area necessary for ties	235,714
We have a total of	249,214

to serve the maintenance of our railways.

The area needed for annual new construction would appear to be:

	Acres.
Ties	44,000
"Dimension" timber and lumber	3,333
Telegraph poles	300
	47,663

RECAPITULATION.*

	Acres.
Annual maintenance of 187,500 miles of track, with 137,615 miles of telegraph lines, requires	249,214
Annual new construction of 5,000 miles	47,633
Total	296,847

Quality of timber required.—The speed and weight of railway traffic demand unconditionally the selection of the best timber. The necessity of imbedding the cross-ties in earth ballast, by which a constant process of decomposition of the woody fiber is induced, requires the most lasting timber. Railway companies use, therefore, the best timber obtainable within a reasonable distance from their lines.

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* This appears rather as a hand-to-mouth calculation, which does not take into consideration the continuous existence of the railroads and of their requirements of wood supplies. Calculating upon present conditions, which require the production of wood at the rate of more than 500,000,000 cubic feet of round timber annually, it would be necessary to arrive at some idea of what forest area could produce such an amount continually as its accretion. A yearly average production of 50 cubic feet per acre for large areas, with a long period of time and tolerably well-stocked forest, can be assumed as a reasonable result. From this it would appear, that to supply continuously the present demand of wood for railway construction would necessitate a reserve of not less than 100,000,000 acres of well-stocked thrifty forest.—B. E. F.

In consequence certain pre-eminently valuable kinds are required in the greatest quantities, and adding to this the general preference given to young and thrifty timber, possessing the greatest toughness and elasticity, it can be readily seen that the time may not be far distant when the wonted supply of those kinds will become exhausted. Many millions of young trees of the White Oak tribe are cut annually, each of which make but one tie. When one locality is exhausted, this scene of slaughter of the most valuable young timber is simply shifted to another. The careful selection of the best material makes the waste throughout necessarily large.

Telegraph poles, required to be straight, smooth, and lasting, are made of Chestnut and Red and White Cedar timber, which abounds principally in the Northeastern and Atlantic States. Tennessee, Arkansas, and Texas likewise, furnish large quantities of this material. Preference is given, however, to Cedar poles grown on the barren uplands rather than to those grown on the sandy lowlands of the Southern States.

"Dimension" timber for bridge construction, lumber for stations, and material for car-building naturally belong to the lumber trade and command the ruling prices obtaining in that industry. It is noteworthy in this connection that, while prices are on the ascendency in the latter, the value of ties is comparatively stationary, lower even to-day in certain sections than ten or fifteen years ago.

Adequacy of supply.—Railways built through timbered districts encounter little difficulty in procuring the needed supply of construction timber, in the selection of which they have had an almost unlimited choice. The abundance and cheapness of wood has exercised a great influence in the shaping of the modes of construction in vogue in a country in which for several generations past the inhabitants have been busily engaged in clearing the land of the timber. Are we to wonder at the accounts of proverbial waste in the earlier days of the country, a popular policy simply unavoidable under circumstances controlling those pioneer periods? But would it be wise to cling to the traditions of the past, refusing to judge impartially the necessities of the future, in which the demands for forest products will ever be on the increase?

The agencies employed in supplying the enormous quantities of ties required by the railway system determine, to a great extent, the amount and price of material offered in the market. In many parts of the country the cutting and hauling of ties to railway stations is performed mostly by the farmers, to whom this labor is a source of ready cash and employment of spare time. Owing to this mode of supply an abundance of material is steadily offered, giving railways full control in the selection of the best quality and in the price paid, while by a regulation of the rates of freight they can prevent an undue export to the treeless sections of the country, or check materially the lumber industry of certain localities. In this way prices are kept down and a show of seeming abundance is maintained which does not in the least prove the supply to be adequate, but merely shows that the great number of people engaged in this industry are willing to haul ties to the railways over distances steadily increasing as the timber nearest the lines is cut off. Immense quantities of tie-timber are thus cut down and delivered to the railways at prices below its real value. At the time the leading lines west of the Missouri River were constructed, extensive tracts of White Oak timber were laid waste in the Western States. And the same process is going on throughout the White Cedar regions of the North, from which immense quantities of ties are thrown on the lumber market. These channels of supply, based solely on considerations of monetary profit, will continue to bring to market the forest wealth of many sections of the land, but in many instances, and at a time not far distant, nature's bountiful supply will be exhausted, and the reckless system of forest clearing will of necessity be a thing of the past. Many parts of the country, once well supplied with valuable timber, have passed through the process of "improvement," but to-day feel quite keenly the loss sustained in former years.

Aside from railway supply, a notable diminution of forest wealth is beginning to be felt by many industries depending for raw material on certain valuable kinds of timber. Approaching scarcity is plainly indicated by steadily advancing prices, and by the difficulty already experienced in the manufacturing centers of obtaining the desired materials. Railway managers acknowledge quite candidly that the present condition of the supply cannot last for an indefinite period, as many leading centers of production are now practically exhausted, necessitating transportation over far greater distances than heretofore.

The discussion of substitutes for wood in railroad construction thus becomes a subject of great interest to the railway world, as it can be predicted with certainty that necessity will soon force the roads traversing the treeless plains to seek a substitute for the wooden tie. The modern steel tie, which thus far has given great satisfaction on European railways, will undoubtedly find extensive adoption in the railway system of America. There are, however, two expedients, already widely discussed and experimented with in this country, by which this pressure upon the most valuable forest products may be sensibly relieved. The one relates principally to railway interests; the other appeals to the intelligence and enterprise of the people at large. They are, first, the adoption of means of preservation by which many kinds of timber heretofore rejected in railway construction, and therefore still in great abundance in many sections, may be made valuable; second, the planting and cultivating of the most valuable timber trees on a scale commensurate with future demands. In support of this proposal to substitute various timbers hitherto but sparingly used in track construction, reference may be made to the experience of European railways with beech, which, together with closeness of fiber to hold spikes, combines the requisite hardness to withstand the concussion of heavy traffic, but lacks durability when in contact with the ground subject to excessive changes in dryness and moisture. When properly treated with an antiseptic the tie, which in its natural state lasts but five or six years, is made to last from ten to twelve.

The same treatment is applied to various inferior kinds of pine, transforming them into valuable material, while in their natural condition they are almost useless for railroad construction. In consequence of the rapid increase of railroads in European countries, and their comparatively small timber resources, these precautionary measures of economy have there been forcibly demanded, and they have also attracted the attention of American railway companies, some of which have experimented quite extensively with the leading processes of timber preservation in vogue in Europe.

The great abundance and cheapness of timber in this country hitherto has made the economy of any expensive preserving process quite doubtful, while the dishonesty with which contracts for preservation have been fulfilled, in many instances resulting in the protection of only an outer shell surrounding the speedily decaying heart, has proved a great impediment to real progress.

The question, however, is only postponed to a time, not far distant, when the price of first-class tie-timber will show a marked increase. It is obvious that the lines in timbered sections, within cheap and easy reach of all the road material needed by them, have no immediate interest in the question of the preservation of the very product in the carrying traffic of which they are principally engaged, and no inducement could lead them to engage in enterprises for which there is neither real nor immediate necessity. The case, however, is entirely different with lines in sparsely wooded districts from which the most available timber has already disappeared, and where forebodings of coming deficiency of home supply are already sensibly felt; yet it concerns more especially the lines on the open plains which depend exclusively on remote forest districts for their supply of timber. On the proverbially fertile soils of these broad prairies soft-wood timbers can be encouraged to grow with great—quite often with wonderful—rapidity, thus securing an abundant supply for track construction and for many mechanical purposes, provided the texture of the wood can be sufficiently strengthened, and made more durable by a process of preservation, the expense of which does not prohibit its general adoption.

Correspondence recently had on the subject with managers and engineers of leading western roads, a résumé of which will be found in the appended summary of correspondence, establishes the fact that the attention of various lines is being prominently directed to this important subject, and also that the Union Pacific Railway is erecting preserving works at Omaha, Nebr., for the special purpose of treating the soft-woods for ties and piling, while the Atchison, Topeka and Santa Fé Road has established extensive works at Las Vegas, N. Mex., operated under the Wellhouse tannin process. *

The necessity of timber culture.—The satisfactory results of forest-tree culture attained by the early settlers of the bleak prairies of the West and Northwest have demonstrated beyond a doubt that timber trees, so indispensable to the homestead on the treeless plain, as material for construction, for fencing, and for fuel, can be raised by each farmer willing to devote to them, for the few years of their earliest growth, the same care and culture that he is accustomed to give to a crop of corn. Tree culture has become a legitimate branch of agriculture, and is practiced by every intelligent farmer from the shores of the Arkansas River to the northmost prairie of Dakota. Well may it be said that in this instance necessity has been the mother of invention, but it has likewise been the faithful teacher of arboriculture.

Belts and groves planted a few decades ago have already furnished abundant material for house construction and for the most pressing economic wants, lending to the prairie farm a manifest protection from the hardships of an open treeless country.

With these gratifying evidences of success before the public, the question suggests itself, why should not railway timber be raised as well as wood material needed by the farmer?

This question has already been extensively agitated, and a few instances can be pointed out where planting has been actually begun. In the majority of cases, however, decisive action has been deferred to a more convenient time, which amidst the constant pressure of the operating service of the railways has not yet come. The indifference of many railroad managers to plans for the preservation of the needed timber supply is easily accounted for when the present abundance of material is taken into consideration on the one hand, and on the other, that the length of time required to grow timber to a size suitable for track construction prevents the existing administrations from inaugurating enterprises in timber culture the full fruition of which is not likely to come during their time of holding the reins of management. The uncertainty of eventual success, owing to the ever-present danger of destructive fires, depredations and unlawful acts of the community, necessitating an extra service for guarding the forests, is likewise a grave objection to a policy apparently within easy reach and control of the great railway corporations, which, as a rule, own large tracts of land capable of producing great quantities of timber.

It is much to be regretted that at the time of the passage of the land-grant acts the necessity of an American system of forestry was but little foreseen, as a clause might justly have been inserted in the act, restricting railways that accepted the valuable grants of the public domain from wasting the forest lands received from the Government, and binding them to a perpetual maintenance of a certain forest area to supply their future wants, either reserved from the primitive forest or established by a system of planting and forest culture.

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* The subject of wood preservation is treated at greater length in Appendix 2 (p. 66), to which reference may be had for further information.

Could the voice of immortal Evelyn, who two centuries ago aroused the people of old England to a full realization of the value of their forests, have been heard in the American Congress of 1850, or had the wonderful results of his early teachings, visible in all European countries, been heeded at the time, the land-grant acts of Congress would have proved a greater blessing to America than they have been.

To sum up briefly the results of the agitation in favor of timber culture by railway companies, it can be stated that, while the imperative necessity of such a movement is freely acknowledged by those best informed in regard to the demands of the present and the outlook of the future, little disposition on the part of the railway companies to enter practically into such an enterprise has so far manifested itself. And it is equally clear that so long as a new departure in forest culture is asked or expected from the heads of the operating service, to whom appeals have in greater part been made, no enterprise on a scale even distantly proportioned to the magnitude of the issue can reasonably be expected, and this mainly from the fact that the service must be managed in accordance with conditions existing for the time being and as they will appear on the yearly balance-sheet of every corporation. Present expediency and restriction of expenditures outweighs, therefore, all possible advantages of the certain future.

The managers of various leading railways, especially those of the Western Plains, formerly called the "Great American Desert," have accorded liberal encouragement to tree culture and home forestry, by establishing experimental stations and nurseries in various sections of their lines, designed to show the possibility of tree culture, to attract settlement, and in consequence to promote the sale of lands granted to them by the Government. As soon as those objects were successfully accomplished the companies withdrew from this inviting field of arboriculture, leaving it to the energy of the settler. It is gratifying that one instance denoting broader views of the necessity of forest culture can be reported—that of the extensive plantation established in Crawford County, Kansas, by Mr. H. H. Hunnewell, of Massachusetts, president of the Kansas City, Fort Scott and Gulf Railway. This far seeing railroad manager and liberal friend of horticulture has caused two sections of prairie land to be planted, in greater part with the hardy Western Catalpa, one section belonging to the above-named corporation, the other his private property. The success attending this timely enterprise, conducted by one of the honored pioneers of American forest culture, Robert Douglas, of Illinois, has so far exceeded the most sanguine expectations that it must be regarded as a landmark in the future development of this great interest.

The trees were cultivated for four successive years, until they had attained sufficient size to fully shade the ground and suppress the growth of weeds. The closeness of their stand is forcing a straight and upward growth with but few lateral branches, which in time will be removed by a natural process.

This brief statement indicates the fundamental requisites of success in timber culture. Proper preparation of the soil, intelligent cultivation of the growing trees until large enough to take care of themselves, and close planting to secure height-growth and straightness of stem, the plan pursued by nature herself in rearing mighty forests. To this is to be added the necessity of selecting the most valuable kinds for the object in view.

Considering the history of the plantation in its relation to the corporation to which it owes its existence, it will be seen that three conditions favored its rise and development, which, under circumstances lacking these favorable influences, would never have taken place, or like former attempts, would have resulted in failure. To illustrate: a man largely interested in railway property, and conversant with the aboricultural topics freely agitated in the United States, issues the order for a plantation. At first his subordinates attempt to execute this order, but soon become disgusted with a work so utterly foreign to the operating service of a railroad. Thus the project is in danger of being dropped. But an ardent pioneer of forest culture steps forward to save so far-reaching an enterprise, hoped for these many years, shoulders the financial risk involved, and performs the work under a great sacrifice of his personal comfort, assisted, however, by the hearty co-operation of the executive officers of the road.

The conditions indispensable to every similar enterprise are, that the order come from the financial headquarters; that there be unerring, sound judgment in the execution of the work, and good-will and co-operation on the part of the executive officers of the respective roads, without which, though well planned and conducted, the work may be greatly impeded by delays, and even practically fail.

In the report of the Department of Agriculture for 1885 there will be found an account of this forest tract, together with one of the growth of the trees planted in three successive years, and of the financial aspect of the enterprise, given by the manager of the plantation, and by the general manager of the Kansas City, Fort Scott and Gulf Railroad; by which it is plainly demonstrated that railway corporations can contract with reliable parties for the planting, cultivation, and care of extensive forest tracts at very moderate prices, thus relieving the executive officers from all cares and responsibilities incident to arboricultural enterprises, in the successful management of which, as a rule, they have no experience, and consequently no desire to enter into them.

Time only can develop the full result of this pioneer enterprise. Whatever success may attend it in after years, these stately blocks of young and thrifty trees, sprung up as if by magic on a treeless prairie, and the lesson in arboriculture imparted by their future development will be of undeniable value to the country at large, demonstrating not merely the possibility of successful timber growth on open, stormy plains, but also the advantages gained by stocking idle and otherwise unproductive lands with valuable seedling trees which will develop into majestic forests.

The time cannot be far distant when the attention of capitalists investing so lavishly in railway properties will be directed towards a closer investigation of this financial question, and when once convinced of the feasibility of timber culture from a financial point of view, the step towards action will not appear so problematic as it must necessarily be before the hard crust of doubt and the uncertainty of eventual success is broken by actual experience, gained by the liberal investments of the comparatively few far-seeing and philanthropic pioneers of American forest culture.

Railway corporations are deeply interested in the perpetuity of suitable material for the maintenance of their thousands of miles of track. The leading managers of the railways of the sparsely-timbered sections cannot fail to see the advantages to accrue in future years from a general interest in favor of timber culture aroused amongst the owners and tillers of the soil; a forward movement which can be most effectually promoted by making the people of every section along the various lines familiarly acquainted with the value and ease of culture of certain kinds of timber, in which not only the railways, but the people at large, are most prominently interested.

No more effectual mode of arousing this interest can be suggested than that of railway corporations planting in various suitable localities along their lines specimen groves or blocks of such kinds of timber trees as are worthy of the greatest possible dissemination amongst the agricultural people. Let this timely enterprise, entailing but comparatively small outlay, and within the reach of nearly every corporation, be conducted in accordance with the best arboricultural knowledge and experience of the day, and above all let the young plantations be properly cultivated until able to take care of themselves, and be protected as far as possible from destructive fires, and success can be looked for with certainty. Let it be remembered, too, in this connection, that a few successful, well-paying orchards, planted in early days, have done more service in the rise and spread of American fruit culture than all the combined efforts of authors and orators on horticultural topics.

SUMMARY OF CORRESPONDENCE WITH RAILROAD OFFICERS.

During the year 1886 a circular was directed to railroad companies, chiefly those located in the western part of the country, for the purpose of obtaining information in regard to the consumption of timber for the construction of their roads, the extent to which they were engaged in the cultivation of timber for railroad building, or in the planting of trees for wind-breaks and as a protection from snow-drifts; and, in general, as to the prospect of an adequate supply of timber for railroad purposes in the future.

Replies to the circular were received from the following companies, thirty-five in all, viz: Atlantic and Pacific (New Mexico); Burlington, Cedar Rapids and Northern; Chicago, Burlington and Quincy; Chicago and Alton; Chicago and Eastern Illinois; Chicago and Northwestern; Chicago, Saint Paul, Minneapolis and Omaha; Central Iowa; Cincinnati, Indianapolis, Saint Louis and Chicago; Cincinnati, Wabash and Michigan; Denver and Rio Grande; Detroit, Lansing and Northern; Hannibal and Saint Joseph; Illinois Central; International and Great Northern; Kansas City, Fort Scott and Gulf; Little Rock, Mississippi River and Texas; Louisville and Nashville; Louisville, New Orleans and Texas; Louisville, New Albany and Chicago; Michigan Central; Missouri Pacific; Mobile and Ohio; Nashville, Chattanooga and Saint Louis; New York, Pennsylvania and Ohio; Northern Pacific; Pennsylvania Railroad; Pensacola and Atlantic; Pittsburg, Cincinnati and Saint Louis; Saint Louis, Alton and Terre Haute; Saint Louis and San Francisco; Southern Pacific; Terre Haute and Indianapolis; Union Pacific; Wabash, Saint Louis and Pacific.

These roads have 45,787 miles of track in operation. In their construction 16,668,423 ties have been used, at an average cost of 35.6 cents each.

The average number of new ties required annually for each mile, to replace decayed ones, is 365; the average duration of ties is 7.2 years.

To the question, "Has your road made any efforts or experiments in timber culture?" ten of the companies reply affirmatively.

The Illinois Central Company report that they planted some Larches in 1872, that they gave them very little attention, and the greater portion of them died.

The Kansas City, Fort Scott and Gulf Railroad Company are distinguished above all other railroad companies of the country for the extent and systematic manner in which they have engaged in tree-planting. A full account of their plantation is given elsewhere in reports from this division.

The Northern Pacific Railroad Company report that experiments have been made with Box-Elder, Cottonwood, Ash, and Willow, but do not give the result.

The Burlington and Missouri River Railroad Company have planted some timber trees, chiefly for protection from snow-drifts in cuts. The trees planted were Honey Locust, Cottonwood, Box-Elder, Maple, Ash, Willow, and some evergreens. Wherever the trees were properly cared for they have grown well. In some places they have been injured by fire.

The Atchison, Topeka and Santa Fé Company report as follows:

"About the time of the construction of our line, in 1870–'72, in the State of Kansas, four or five experimental nurseries or plots of ground, planted with young trees, were started at different points along our line, from 200 to 300 miles west of the Missouri River. All the hardy trees common to Eastern Kansas and Western Missouri were grown from the seeds, and for five or six years were carefully cultivated. After that time they were left to care for themselves. They made good growth and seemed perfectly at home in what was then a treeless country. Since that time settlers have fully occupied the ground, and many of them have grown trees in great numbers. Our aim, principally, was to show the new settlers what trees were suitable to plant in this section of country."

The Missouri Pacific Company report:

"In Mississippi County, Missouri, 250,000 Catalpa plants are in cultivation by the railway company, and the experiment promises satisfactory results; but sufficient time has not elapsed since planting to speak with certainty."

The Southern Pacific Railroad Company make the fullest report of any. They say: "In the year 1877 it was determined by the directors to try the experiment of tree-culture through the various sections of country traversed by the line of railroad controlled by the company, with the following objects in view:

"(1) To demonstrate the capability and value of the land.

"(2) To test the value of certain woods for railroad purposes, and the practicability of their economic cultivation.

"(3) To remove the sterile and forbidding appearance of the stations and section houses in the treeless plains and valleys, by surrounding them with fruit and shade trees.

"It was determined to carry this work on under the Superintendent of track, and it was specially put in my charge, with instructions to make the current expenses as small as possible.

"My first effort was directed towards the culture of the rapidly growing varieties of the Eucalyptus on the margin of the right of way, where it was available, with a view to utilize the growth and to test the economic value of the wood.

"For this purpose some thousands of tree-plants were purchased in the nurseries of Oakland and Hayward and planted along the right of way of the lines running through Alameda County, California. The total number planted in this way was about 44,000, mostly *Eucalyptus globulus*, but including also a good number of *E. amygdalina* and *E. rostrata*. To anticipate this experiment as a test of the wood, about a thousand telegraph poles were procured, of the young growth of the *Eucalyptus globulus* or Blue Gum, and also 226 fair-sized railroad ties. The telegraph poles were placed in the line along the San Pablo and Tulare Railroad. The railroad ties were placed in the track near Rose Creek, Nevada, on the Truckee division, Central Pacific Railroad. This point was selected because it was found that there the destruction of ties by rot was extremely rapid. Mr. Vandenburg's report of the test of the Eucalyptus for telegraph poles showed that while they were strong and tough, and bore up the wire well under all circumstances, yet they did not last well, as they were inclined to rot in the ground, and just at the surface of the ground were attacked by the larvæ of some large beetle. The Eucalyptus ties placed in the sandy soil of Rose Creek very quickly showed a tendency to check or crack in an extraordinary manner, so that in some cases it was found difficult to find a place on them suitable to hold a spike; otherwise the ties were very strong and lasted well. After being four years in the track, Roadmaster Browning reported 'no sign of decay.' After being six years in the track, slight signs of rot were reported, and two out of two hundred and twenty-six were removed for being split. After seven years in the track, two inches of rot was reported, and seventy-three were taken out of the track. This would show the Blue Gum ties comparing in durability with best Yellow Pine, which is our best second-class tie.

"The trees planted along the track in Alameda County showed great thriftiness of growth, and in a few years demonstrated that wood could be produced in this way with surpassing rapidity. In four years some of the trees had reached a height of 24 to 26 feet and a diameter of 8 to 10 inches. At this point it was deemed expedient to terminate the experiment, and the trees were cut down and used for engine wood.

"In 1877 Mr. C. P. Huntington sent a box of Catalpa seed (*C. bignonioides*), with a strong recommendation that it be tested with a view to cultivate a plantation for tie-timber. The wood of the Catalpa is coarse-grained and light, but it has the reputation of being the most durable under ground of all timber. Cases are quoted of its lasting, buried in the ground, eighty years and upwards without showing signs of rot. (Ohio Agricultural Report, 1871.) The Goshen Branch, just built at this time, passed through a treeless region where the land was moist and very fertile, hence it was deemed a good place for the Catalpa experiment, and a parcel of land, fifteen acres in extent, was selected for that purpose in the town of Hanford, Tulare County, California. This tract was planted with Catalpa trees raised from the seed sent out by Mr. Huntington. The trees were set out 8 feet apart, north and south. They throve remarkably well, growing almost as rapidly as the Eucalyptus trees about San Francisco Bay. But in the course of time the company received what was thought to be a very advantageous offer for this land, and it was sold. Though the experimental grove was thus taken out of our hands, it yet continues to flourish, and I learn from the report of the company's agent that these trees, which are now seven years old, have attained a height of from 50 to 60 feet and are from 8 to 12 inches in diameter. They have now, therefore, reached a size when some of the trees might be cut for ties. They were planted 326 to the acre. If one-fourth of these could be cut for ties, and by splitting them through the center, as is suggested, four ties be made from a tree, this ground may be considered to bear already a very valuable crop.*

"It was considered that the most important work in hand was that of planting out about the stations and section houses. To have a cheap and convenient source from which to procure tree-plants it was determined to establish two nurseries, one in the northern, the other in the southern portion of California. For the first a block of land belonging to the company was selected in the town of Chico; for the second locality we took a portion of the right of way situated between Sumner Station, California, and the Kern River. The strong clay soil of Chico was relied on to produce the plants of the Catalpa, Locust, Walnut, Poplar, and certain fruit trees, while the sandy soil and hot climate of the Kern River valley was expected to produce the different varieties of the Eucalyptus, Acacia, and Pepper Trees, and certain trees of arid habitat.

"From these sources we soon had an abundant supply of tree-plants. In the spring of 1877 the whole of the country east of Tulare Lake and south of the present town of Tulare was an unoccupied waste, used only sparingly for pasture. With a view of demonstrating that this treeless waste could be made fit for homes, a half section of land was selected in the midst of this area at a point just south of Tipton. This was inclosed with a fence and planted with Eucalyptus and Acacia trees, and for their maintenance an effort was made to get an artesian well, which resulted successfully. A good flow of water was obtained at a depth of 403 feet. Stimulated with this water the tree-plants grew fairly well and presented the appearance of a grove.

"The example was followed by settlers, who bought land and soon were sinking artesian wells and making homes throughout this section, showing that one object of the experiment had been accomplished. We soon found, however, that the Blue Gum was too susceptible to frost to thrive permanently at Tipton. Each winter biting, frosty air pours down from the mountains out of the cañon of Deer Creek on to this particular tract, thus killing the tender Blue Gums in spite of their strong summer growth.

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*Irrigation has been extensively carried on in this region, and its summer climate is undoubtedly more humid than is generally the case in the interior valleys of California. However this may be, the Catalpa trees planted along the company's lines at all the principal stations in California have not thriven well, apparently being ill-adapted to the long warm and rainless seasons.

"The nurseries at Chico and Sumner (Kern River) furnish tree-plants, and each spring during the period adapted to planting they were distributed along the lines of railroad and planted about the stations and section houses.

"In some localities, notably in Nevada, great difficulty was found in making the trees live. This resulted partly from the altitude and severe climate, and partly from selecting trees ill-adapted to the locality. It is true, we know, that Cottonwood and Quaking Aspen and the like would flourish at the most difficult points, but it was deemed worth while to try what could be done with more durable species and with fruit trees. In this way it was not by once planting, but by many times planting, that the stations in the treeless wastes were gradually embowered. Often, after trees were well started, the carelessness of an employé would allow them all to die off again.

"The situation of Kern River was found to be excellent for a nursery, but for the sake of economy it was abandoned in favor of Tipton, where the plantation and nursery could be consolidated. Most of the trees planted out along the Southern Pacific, as far east as El Paso, were raised in this nursery from the seed.

"In extending the tree-planting through Arizona and New Mexico an unexpected difficulty was encountered. We had looked for trouble from heat and drought, but we found the most serious trouble to arise from frost. We never expected to find, as our meteorological observations now show, a minimum temperature of 8° and 10° for stations in Arizona.

"In consequence of this lack of sufficient data, the trees sent to that section for several seasons have been frost-bitten. As the first experience of this kind was thought unusual and exceptional, the same kinds were tried again. I believe I can now report that the present stations throughout California are sufficiently supplied with living trees, so that, with reasonable care, the beauty and advantage to be derived from them will be constantly on the increase."

To the question, "Have you planted trees for wind-breaks, as a protection against snow-drifts, and with what success?" thirty-four, or most of the companies from whom reports were received, reply emphatically, "No."

The Northern Pacific Railroad Company says: "Yes; but it will take two years to determine with what success."

The Burlington and Missouri River Company say, "We do not consider that our trees planted for snow protection are a very great success. In the winter, when protection is needed, the foliage is all off, and the railroad 'right-of-way' being narrow the trees must necessarily be too close to the road to make an efficient snow-break."

The Chicago, Saint Paul and Minneapolis Company report good success, but give no particulars.

The report from the Missouri Pacific Company objects to the planting of trees for wind-breaks or as a protection from snow on account of their obstructing the view at highway crossings, and because it would involve the expense of purchasing land on either side of the road so that the trees might be set further apart than they can be with the ordinary width of road. It is alleged that where the road is only 100 feet wide rows of trees on either side, instead of protecting from drifts, cause the snow to lodge there and become more troublesome than it would be without the trees.

To the question, "Have plantations along your line been materially damaged by fire?" twenty-two companies have made reply. The general tenor of these replies would indicate that the losses by fire are not great.

The Louisville and New Albany Company say: "We have had very little damage by fires to forests, and do not think this would in any way discourage tree-planting."

An officer of the Hannibal and Saint Joseph Railroad Company says, "I am not aware that any plantations along the line have been materially injured by fire, nor do I consider fire a danger sufficient to discourage tree-planting."

Report from the Burlington and Missouri River road says: "Private groves along our road have not been seriously damaged by fire, and they do well in nearly every case; private parties being better able to take care of trees than the railroads, having them near by where they can be constantly looked after, and not endangering them by fire, as the railroads necessarily must do in running their trains, and are not so liable to have them burned."

An officer of the New York, Pennsylvania and Ohio road says: "I would advise to make the plantations at some distance from the railway. Fires are frequent near the railway.

The Louisville and Nashville Company report: "Trees and hedges have been injured by fire along the line of railroad."

The Michigan Central Railroad report says: "The damage is serious where grass is allowed to grow; otherwise not."

The Union Pacific Railway Company report that the damage done by prairie fires has been discouraging, but in that proportion as the land becomes occupied by settlers the danger of fire is diminished.

To the inquiry whether the companies would be willing to expend a small amount annually in tree-planting, the general tenor of the replies is in the negative. Some would be willing to engage in experimental planting if others would unite with them, but few, if any, roads seem to be impressed with a sense of the importance of undertaking the work of planting for their own benefit.

From the Pennsylvania Railroad Company comes this reply, which may be taken as a specimen of the general feeling on the subject: "To this question I would answer yes, if I were the company. But, considering that about twenty-five years would be needed to get White Oak large enough for ties, it is hardly probable the importance of timber culture will be recognized sufficiently to even spend a small amount, say $500 per year, systematically for this."

The Wabash, Saint Louis, and Pacific Company says: "The company would probably consent to make a small expenditure annually in furtherance of tree-culture. Timber has heretofore been so abundant and cheap that there has been but little necessity for taking the matter into consideration and giving it any attention. It is of great importance and should not be longer delayed."

To the inquiry whether the lands along the lines of railway are too valuable to be profitably devoted to tree-planting, while some roads report much of the land as being of high value, they generally agree that there is a sufficient quantity of inferior value which might be more profitably used for the cultivation of trees than for any other purpose. The Louisville and New Albany Company say, for instance, "Our line is mostly through cultivated lands, but there are many tracts that would be just the thing for tree-culture, while of no value for any other purpose." The Union Pacific Company say that there is an abundance of land fit for tree-culture along the company's lines, but it would not be advisable to plant and cultivate at the company's expense, for they cannot even protect from thieves the small patches of timber on the streams that were formerly found in many sections of their grant.

To the question, "Would not tree-planting by railways be facilitated if each road had in its employ an officer sufficiently acquainted with the relative value of trees and modes of planting to superintend all work of this kind ordered by the managers?" the replies are almost unanimously in the affirmative. Most of the companies think such an officer would be indispensable, while a few think the existing officers of the roads could manage the business

Appendix 1.

STRUCTURE OF CERTAIN TIMBER-TIES; BEHAVIOR AND CAUSES OF THEIR DECAY IN THE ROAD-BED;

TOGETHER WITH EXPERIMENTS ON THE ADHESION OF SPIKES.

By P. H. DUDLEY, C. E.

The extensive railway system of the United States will this year require 60,000,000 ties for repairs, and as the lines are yearly extended the number required for this purpose will be increased. Expressed in board measure this represents approximately 2,160,000,000 feet, a large quantity, though, for our great country, only comparatively so; for could the supply be cut indiscriminately, and from all kinds of timber, our forests would continue to meet the demand for years to come. But the supply is limited to special kinds of woods, and ties are cut chiefly from trees 10 to 12 inches in diameter and from thirty to sixty years old. This is one of the serious phases of the question; for this consumption of young and thrifty trees reduces the future supply of timber faster than would otherwise be the case.

In the Eastern and Middle States the supply of timber adjacent to railways has been largely exhausted, ties for these roads coming from forests some distance away; and, with the price constantly advancing, how they will procure ties a few years hence is a serious question with railroad officials. But few railroad companies are in position to grow their future supply of timber, and if they were, it would be twenty-five years before they could derive much benefit from such a course.

CHECKING UNNECESSARY CONSUMPTION OF TIMBER BY PRESERVATION OF TIES.

The railway companies can at once take more effective measures to increase the durability of the ties they must use, and thus to check the present consumption of such great quantities of timber. In former years many efforts were made in this country to preserve ties by artificial processes; but the cost was so great and timber so cheap, while the results were only partially successful, that for the time being all methods for the preservation of ties were abandoned. But at present the case is different. In many localities timber is two or three times as expensive as it formerly was. Chemicals are much cheaper and money bears a lower rate of interest, so that, upon the score of economy alone, it will now be expedient to do what was unwarranted a few years ago. Little inquiry was made as to why so many of the preserving processes failed.

THE DECAY OF TIMBER AND TIES DUE TO THE GROWTH OF VARIOUS KINDS OF FUNGI.

In dry situations, as in roofs of buildings, or when submerged in mud and water, seasoned wood will last for centuries; but it decays in places where it is warm and moist (from 40° to 120° Fahr.). Formerly the decay of timber was generally ascribed to slow combustion (Liebig's Eremacausis), but it is now known to be due to various kinds of fungi, the presence of many of which microscopical investigations have demonstrated.

As regards the relative position of the fungi in the scale of plant-life, it is perhaps only necessary to say they are a great group of plants of low organization, destitute of chlorophyll, and bearing neither leaves nor flowers. Instead of seeds they produce microscopic spores, which are freely disseminated by wind and water. They are dependent chiefly upon higher plants for their nutriment, appropriating the already elaborated material found in the tissues of these hosts. Nearly 50,000 species of fungi have been described, many of which grow on or in the wood of trees.

A large number of the measures formerly adopted to prevent and check decay, especially that of unseasoned wood, by confining the moisture, were the most effective in causing the fungi to grow, inducing, it is believed, the decay of the wood. Thus it is a well-known fact that painting green timber will hasten rather than retard its decay; the paint, by retaining the moisture, furnishes a necessary condition for the germination of the inclosed spores. This also is probably the explanation of the failure of so many of the other preserving processes. The chemicals, or other substances used, formed an exterior coating* like paint, thus retaining the moisture and allowing the fungi to grow on the inside, causing the so-called "dry-rot." If the timber be thoroughly seasoned, an exterior protection from moisture is sufficient to prevent decay. The rotting in four or five years of many of the earlier wooden bridges, which were painted before they were seasoned, is familiar to all railroad men, while those unpainted lasted much longer. So, too, unpainted covered wooden bridges were found to be the most durable, from the fact that the timber was kept so dry as to preclude the attacks of fungi. The timber, if not too large, became thoroughly seasoned, and in that condition was practically indestructible.

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* See Carbolineum as a Protection against the Decay of Wood, p. 104.

Ties should be seasoned.—Simply seasoning ties would add much to their durability. They should be piled so as to have a free circulation of air under and about each tie. The top of the pile should be inclined so as to shed water. As soon as the trees are felled the bark should be removed in order to facilitate the seasoning of the wood. Large timber for switch-stands, trestles, floor beams, and stringers for bridges should be seasoned under cover to prevent the sun from seasoning only an exterior layer, thereby preventing the escape of moisture from the interior and inducing interior decay. Station platforms of timber should have a circulation of air under them, otherwise they are quite liable to be attacked by some of the fungi. In many cases spruce planks in these structures have decayed in less than two years.

The appearance of some of the fungi present upon and in piles of timber is, perhaps, familiar to all track managers, but we have been taught so long that this is simply the accompaniment of decay, instead of being its inducing cause, that such effective measures to prevent rotting have not been taken as might have been and will now be adopted since the cause is better understood.

Preservation of ties.—In most cases thorough and proper treatment will preserve ties so as to double their life as far as decay is concerned; but the method that is most suitable for one kind of wood may not answer for another of different characteristics. This will be more apparent upon examining the structure of the woods illustrated. To be successful the conditions of each case must be considered; not only the kind of wood, but whether it is seasoned or not, and what the final surroundings are where it is to be used. For railway ties, we can say in general that the treatment must be such as will do one of two things: keep the wood dry; or, if it is to be used in a position where it will be moist, the antiseptic must be sufficient to check all fungous growth or fermentation, to do which the cells of the wood must be thoroughly impregnated. The success of Dr. Boucherie's first process of forcing a solution of copper sulphate through the green wood was due to the complete impregnation of the wood-cells. But this plan of treatment requires much care and skill to be effective. The late Dr. Hough, in Vol. IV. of the Report on Forestry, p. 165, says:

> "Upon the Flushing Railroad Burnettized ties were used in building the pile-work near Flushing village in 1868, the timber being green Spruce 12 by 12 (inches), sawed and used as stringers, from 4 to 10 feet above the level of salt-marsh meadows. They appeared to have been thoroughly treated to the heart. There being some deficiency in the supply the work was completed with White Pine stringers (not Burnettized) of the same dimensions as the Spruce. Upon repairing the pile-work the Burnettized timber was found decayed in the heart, leaving a shell of from 1 x 3 inches, while the Pine was comparatively sound, some portions being merely sap-rotten an inch or so deep on the outside.
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> "The roadmaster then in charge, and who writes apparently without the least interest or prejudice, considers the Burnettized timbers unsafe for railroad structures on account of its decaying at the heart and leaving a shell that is sound, which would naturally lead employés to regard the timber safe for trains after it had reached a

degree of weakness that was altogether dangerous within. He thinks that this process has a tendency to produce dry-rot, especially of Pine or soft-wood.

"It would, however, be unfair to draw conclusions from American experience, and perhaps it would be just to attribute some, at least, of the failures that have followed to the inexperience of workmen and to the superficial and imperfect manner in which these processes have been applied."

The last sentence explains the matter. The fault was not in the antiseptic but in the manner of its application; the heart-wood was not impregnated with a sufficient quantity to protect it from the fungi.

STRUCTURE OF THE WOODS UNDER CONSIDERATION.

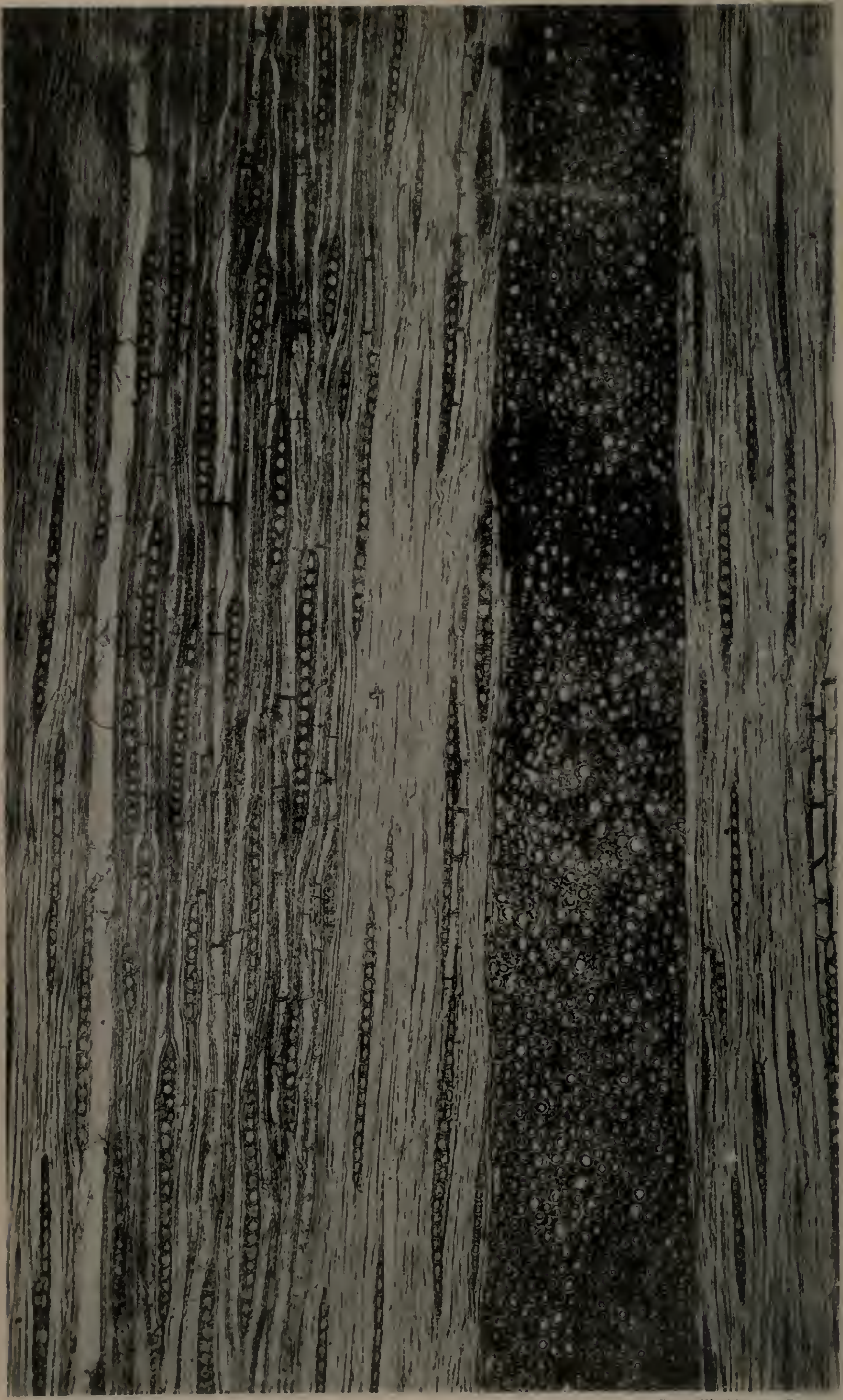
In the following pages will be considered the structure and nature of some timbers with reference to their use as railway ties, and their special requirements in regard to preserving processes; namely those which form the bulk of our wood supply for railway purposes—White Oak, Chestnut, Cedar, Yellow Pine, Hemlock, and Tamarack or Larch.

The oak and chestnut belong to the Angiosperms, and the cedar, yellow pine, hemlock, and tamarack, to the Gymnosperms, all of the latter having the general characteristics and structure of the Coniferæ, but differing from each other in detail. In the first two the cell-structure is entirely unlike that of the last four, being far more complex and highly differentiated, the inner portion of each annual layer having from one to three concentric rows of large ducts, while smaller ones are distributed through the entire layer.

All these trees are Exogens or outside growers, and if we look at a transverse section of any of them of the natural size we see it is composed of a series of annual rings, each representing a distinct period of active growth, generally only one ring forming each season, but often varying in thickness. For instance, in the White Oak (*Quercus alba, L.*) a layer of a poor season's growth may not have the full number of the hard, dense fibers which give hardness to the wood. To some extent this is true also of the chestnut. In the other woods under consideration each layer will have more nearly its proper proportion of the different fibers, though the layer may be thin. Through each annual ring pass the medullary rays, which extend from the bark to the pith, and if a small section be magnified the general characteristics of the entire layer are seen; if the section be taken from the sap-wood the structure is not so complete as in heart-wood, and the cell contents are not the same. In the mechanical destruction of ties the ease or difficulty with which the rings separate has much to do with the wearing capacity and consequent durability of the ties. This feature differs in all the woods under consideration, and will be specifically treated for each one.

PHOTOMICROGRAPHS OF THE MAGNIFIED STRUCTURE OF THE WOODS.

The photomicrographs accompanying this report are all enlarged to one scale, namely, 100 diameters, and by employing the metric scale in making a measurement, and dividing by 100, the natural size of

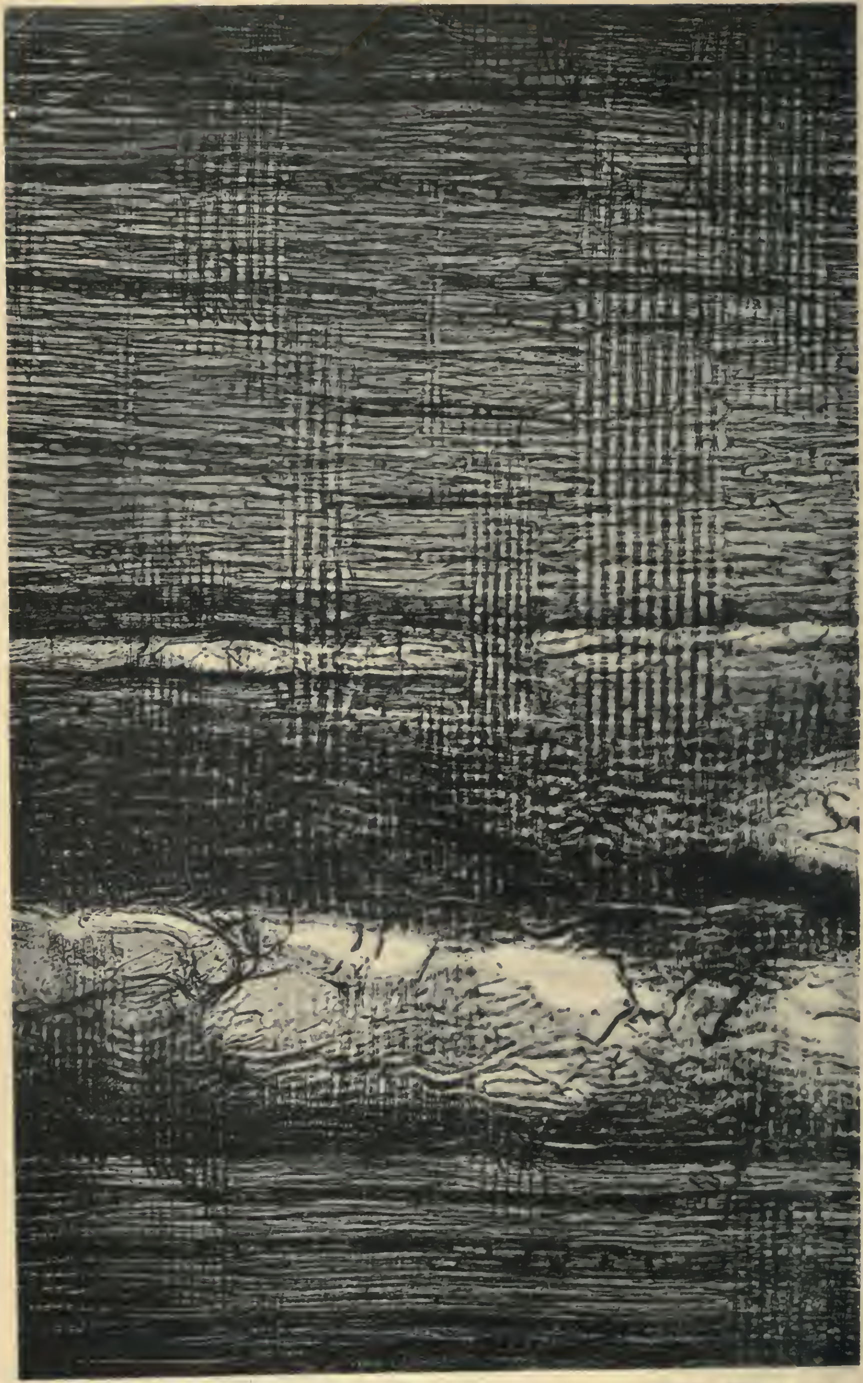


Photomicrograph by P. H. Dudley.

Bell Bros., Washington, D. C

251. Quercus Alba, Linnaeus; White Oak.

Tangential Section × 100 Diameters.

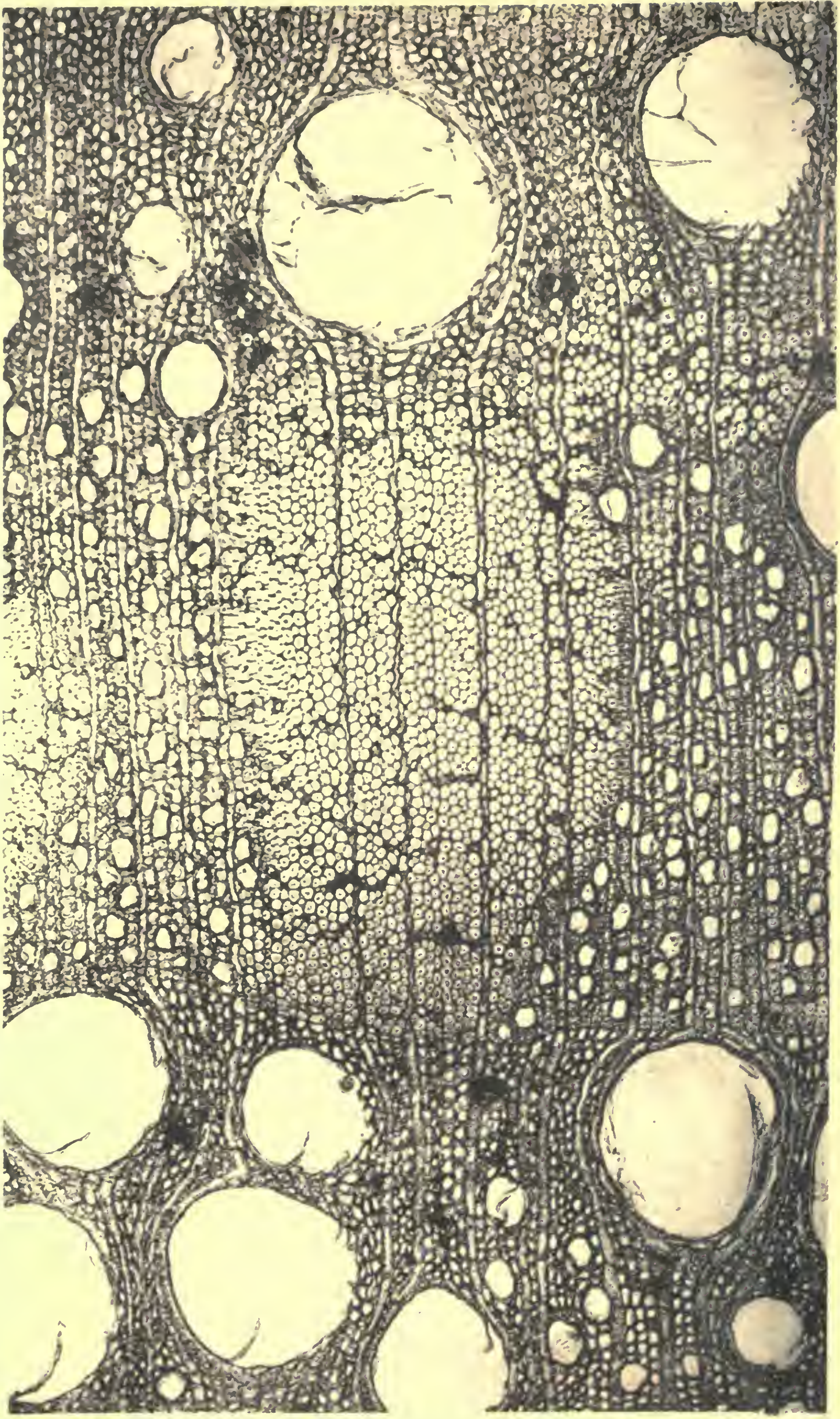


Photomicrograph by P. H. Dudley.

Bell Bros., Washington, D. C.

251. Quercus Alba, Linnaeus; White Oak.

Radial Section x 100 Diameters.



Photomicrograph by F. H. Dudley

Bell Bros., Washington, D. C.

251. QUERCUS ALBA, LINNAEUS; WHITE OAK.

a cell or the thickness of its wall can be obtained. For this amplification the field of the objective covers an area of the specimen equal to one-tenth of an inch in diameter, which is enlarged to 10 inches, the photomicrograph being taken from the portion thus viewed with the same amplification retained. To show the entire structure of the wood a photomicrograph of three different sections is required, *i e.*, transverse, tangential, and radial. In the transverse section the cells are cut across, showing some in their largest diameter, while others are cut at varying portions of their length, and, therefore, show different diameters. All of these transverse sections are so arranged that the top of the page points to the center of the tree, and the bottom of the page to the outside of the bark. The lines running down the page indicate the medullary rays, which extend outward through each layer of wood as it is formed. The views of the other sections will be understood from the special description under each species.

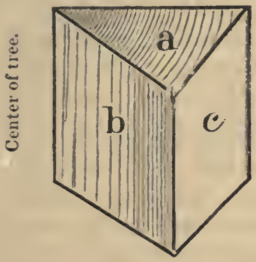


Diagram illustrating sections: *a*, transverse section; *b*, radial section; *c*, tangential section.

WHITE OAK, *Quercus alba*, L. No. 251.*

The photomicrograph of the transverse section of the White Oak is from an annual ring of medium thickness, and a striking feature in its appearance is the concentric circle of ducts in the early spring growth of wood; in the thick rings sometimes there are two or three rows of ducts, the third one being of smaller size than the others. The first row forms in the spring as the leaves are opening. The largest duct in the illustration is round and .013 of an inch in diameter; some are smaller, and others flattened or elliptical. Except when first forming these ducts are never open, as usually stated, but are filled with delicate tissue.† This tissue is so delicate and its cells so large that in cutting the sections it is more or less removed by the section-knife. It is, however, quite durable, for in decaying ties this tissue in the ducts is still intact after many of the surrounding wood-cells are decomposed. During growth, fluids pass through this tissue by osmotic action. Surrounding these ducts are small cells, which are termed tracheids, having minute thin places in their sides; the middle lamella of the cell, however, is not visibly perforated. Some cells containing starch are also intermingled with these tracheids. If the tree is not vigorous or the season favorable for a large growth there are only a few other cells formed, and the annual layer will be narrow and imperfect; and if the entire wood is made up of such rings it has a low specific gravity, is "brash" and not strong. Such wood is not suitable for wheel-pieces of car-trucks, and when used for ties the rails wear down into it as they do on chesnut ties. In an annual layer of vigorous growth large bundles or masses of hard, dense fibers are seen just outside of the concentric circles of ducts, and when fully formed extend through the outer part of the layer. These fibers vary in diameter from .006 to .0075 of an inch. Such bundles or masses of hard fibers give to this wood its peculiar hardness and toughness, making it so valuable for railroad ties. The medullary rays run through the bundles and at frequent intervals are intersected by cells running parallel to the axis of the tree, thus connecting radiating bundles of medullary rays, and dividing a mass of hard fibers into small rectangles. On either side of a mass of hard fibers will be seen a series of small flattened ducts about .001 of an inch in diameter, surrounded by small tracheids and some of the small wood-fibers. In this transverse section only single lines of the medullary rays are seen, but large bundles do occur, and a portion of an end view of one will be seen in the tangential section. Near the top and bottom of the illustration can be seen the lines where the annual layer joins others. The illustration of the radial section shows it to have been made through a mass of dense fibers, exposing also the exterior and interior of one of the large ducts. The single rows of cells running down the page are the medullary rays. This view shows also the firmness and solidity of the wood. The hard fibers running across the page give but little indication of where they join or interlace. One of the ducts shows the surrounding tracheids and also the cells of the medullary rays crossing the duct.

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* The botanical names are those used by Prof. Sargent in his report on the "Forest Trees of North America," Vol. IX., of the Tenth Census; the numbers refer to those used in that work.

† *Tyloses,* a peculiar cell-structure found in the ducts of many of our timber trees.

In the tangential section, as already stated, are seen the ends of the cells composing one of the great bundles of medullary rays so common to this wood; but few of the cells are as large as .001 of an inch in diameter, most of them being much smaller. On either side of this are the hard, dense, woody fibers, interspersed with small bundles of medullary rays of a single row of cells superimposed one above the other. From the views of the structure of this wood it is seen to be one of considerable hardness and density.

Specific Gravity.—For the heart-wood, this ranges from 0.65 to 0.90. In Vol. IX., of the Tenth Census, Professor Sargent reports the average of thirty-one pieces, dried at 100° centigrade, as 0.7470. Ties will never be found as dry as this, and in general the average will be much higher.

In wet places oak ties often become water-soaked and will sink when thrown into the water.

Change of sap-wood to heart-wood.—The sap-wood of the White Oak changes to heart-wood in ten to fifteen years, much earlier than that of some of the other oaks. This is a valuable feature, as ties are cut mostly from small timber of the proper size and flattened on two sides, leaving the sap-wood on the remaining sides. In many cases the bark is not removed, but it should be at the time of felling the tree, especially if the temperature be about 50° or 60° F. If the wood is cut during active growth the sap furnishes a good medium for the growth of various ferments, which, if special care is not taken to prevent their growth, will affect the sap-wood and eventually the heart-wood. When such fermentation has taken place and is afterward checked by drying, the wood is discolored and is called "dozy," and will rot quickly when placed in the road-bed subject to conditions of warmth and moisture.

NOTE.—The controversy as to the influence of the time of felling on the durability of the wood cannot yet be said to be definitely closed. The most recent investigations under this head, published by Professors Hartig, Poleck, and Dr. Lehmann, would indicate that the question cannot be answered generally, but that the answer is dependent on different conditions in each special case.

The "dry-rot" fungus (*Merulius lacrymans*, Schum.) being found to be the principal destroyer of the wood used in building, Professor Poleck was induced to examine the mineral constituents of timber felled in the winter and in the summer with regard to the requirements of this fungus, and was led to state that the summer-felled timber affords a better supply of nourishment to the fungus than that felled in winter, the former being five times as rich in potash and eight times as rich in phosphoric acid as the latter. The experiments which confirm this view were conducted with blocks of timber inclosed in casks. Unfortunately, later on, Professor Poleck discovered that the timber procured for him, purporting to be winter-felled wood, was in reality raft-timber; and he has ascertained that timber which has been immersed in water is no longer liable to the attacks of "dry-rot," the effect of the water being to dissolve out slowly the albumen and salts, thus depriving the fungus of the necessary nutriment for its development. So much so is this the case that in Alsace it is customary to specify that only raft-timber shall be employed.

In opposition to the theory of Professor Poleck a number of experiments were carried on by Professor Hartig. In the first place he shows that at the end of April the sap has not risen in the timber, and that no mineral matter can have been stored up in the wood-cells which were not present at the beginning of the winter, and that the true summer-felled timber must, if anything, be poorer in mineral salts than that felled in the winter. His analyses confirm this view, showing 8.42 per cent. of phosphoric acid in winter wood as opposed to 5.89 per cent. in summer-felled wood; and while Professor Poleck insists upon the necessity of phosphoric acid for the growth of the fungus, Professor Hartig lays most stress upon the presence of ammonia or potash salts as being essential.

Professor Hartig's experiments made with pine and fir, felled for the purpose and stored in a specially constructed cellar, are most elaborate and minute, the general result being that both summer- and winter-felled damp fir and pine (two kinds of woods behaved alike) lost equally in weight. When, however, dry winter wood was contrasted with wet winter wood, the results were astonishingly different. In the case of fir the dry wood lost 11 per cent. in weight, while the wet wood lost 23.1 per

The wood of the White Oak is the one most desired by railroad companies for ties. In the primitive forests the growth was very general in those sections of the country where railroads were constructed, and its great value has been fully demonstrated by long experience. The demand for ties of this wood has been so imperative that large extents of territory once covered by this valuable timber have long since been denuded; what remains is so scarce and valuable that few companies are now able to obtain a supply of second-growth for ties.

The oak holds a spike with great tenacity, and thus the rail is firmly fastened to the tie, a feature the importance of which is entirely overlooked by people who have not had practical experience in the matter. The wearing down of ties under the rails is not due alone to the ease of indentation, but largely to abrasion. The softer the wood the less firmly the spike is held, and if there is more or less looseness of the rails an abrasion takes place more rapidly than when they are held firmly to the tie. This fact has been determined by practical tests. Alternate ties under the same rail have been bolted to the rail, and the abrasion was less rapid on them than on those which were spiked. I am well aware of the prevailing opinion in the New England States, where the Chestnut is so extensively used for ties, that were they to attempt to change to oak ties they could not draw the spikes to make the adjustments in their rails, but would break off the heads of the spikes in the trial. Against this opinion, however, we have the experience of the main lines, with a large mileage and tonnage. They prefer the White Oak, experiencing but little trouble in drawing spikes, and they would not use any other wood, except that its scarcity and cost have compelled them in many cases to do so.

Durability.—White Oak ties last from six to ten years. Seven years' duration is considered good under heavy traffic on rails with a 4-inch base. Longer wear of course is had under broad faces of 8 to 10 inches. The moisture which collects around the spikes and under the rails eventually softens the injured fibers, and fermentation is set up in two to three years, depending upon local conditions of moisture and heat combined, the most rapid fermentations occurring in localities where the warm season is the longest. The decay of the ends and central

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cent.; but in the case of pine the loss in the dry wood was 13.3 per cent., while in wet wood it was only 13.6 per cent.

Comparative experiments with heart-timber of fir and pine, as contrasted with the outside planks, showed that while in the fir the heart was destroyed more rapidly than the outside layers the reverse was the case in the pine.

Very unexpected results were obtained when the wood was in contact with various substances, as sand, coal-dust, ashes, garden-mold, etc., from which it would seem that clear sand is worse for filling-in between the joists than a mixture of sand and plaster, while dry rubbish from old buildings is better filling material than coal-dust

The question, then, of the best time of felling, as regards the lasting qualities of timber, cannot yet be considered as settled, and the matter of handling timber after felling is the point of most importance.—B. E. FERNOW.

portions of White Oak ties as a rule follows closely upon that under the rails, especially that portion of the tie which is surrounded by or underneath the ballast. In gravel ballast, oak ties decay more rapidly under the ballast than in the fully exposed parts. In most localities the decay of the oak is retarded by imbedding the tie in the ballast as little as is compatible with the stability of the track. The layers of wood under the rails separate from each other by the breaking-through of the tracheids between the large ducts, yet not as readily as in the Chestnut, but the massive bundles of medullary rays of the oak to some extent check the breaking or crushing of the tracheids, and offer considerable resistance to the undulation of the rails and consequent abrasion of the ties. The apparent injury to the White Oak ties by spiking is not as great as it is to the other woods under consideration, but it is sufficient to shorten, to some extent, the life of ties used. Boring holes for the spikes would prevent much checking of the wood, and a proper-sized hole would increase the adhesion of the spike, as shown by tests.*

Time of cutting White Oak for ties.—The season of cutting affects the heart-wood much less than it does the sap-wood. Great care must be taken of timber cut from April to July, as the large amount of sap elaborated at this time furnishes a favorable condition for the development of fungi, first involving the sap-wood and then the heart-wood. For a like reason care must also be taken of timber cut from July to November, as the sap-wood is liable to be affected; but timber cut in winter is less liable to attacks of fungi at once, from the fact that as a rule the temperature is too low for such growths, and the wood is more likely to get partly seasoned than if cut in the summer.†

PRESERVATION.

This has been accomplished by "Kyanizing" and "Burnettizing" and by the use of copper sulphate. But the treatment must be long-continued to insure full penetration into the wood; otherwise it will be a failure.

FUNGI.

The sap-wood of White Oak ties in the ground is quickly attacked by *Polyporus versicolor*, Fr., the fungus often being found fruiting on timber in the main tracks. The past season I have found it growing to some extent upon the heart-wood of this class of ties, showing that under favorable conditions it can destroy the heart- as well as the sap-wood.

Dædalia quercina, Pers., is often found growing on the sap-wood of these ties, and destroys them with considerable rapidity.‡ *Polyporus applanatus*, Fr., attacks the heart-wood, and is very destructive, though it is rarely found fruiting in the main tracks. *Lenzites vilas*, Pk., is often found upon the White Oak ties of bridges.

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* See Table VI. on Adhesion of Spikes, p. 58; also note and tables on p. 62.

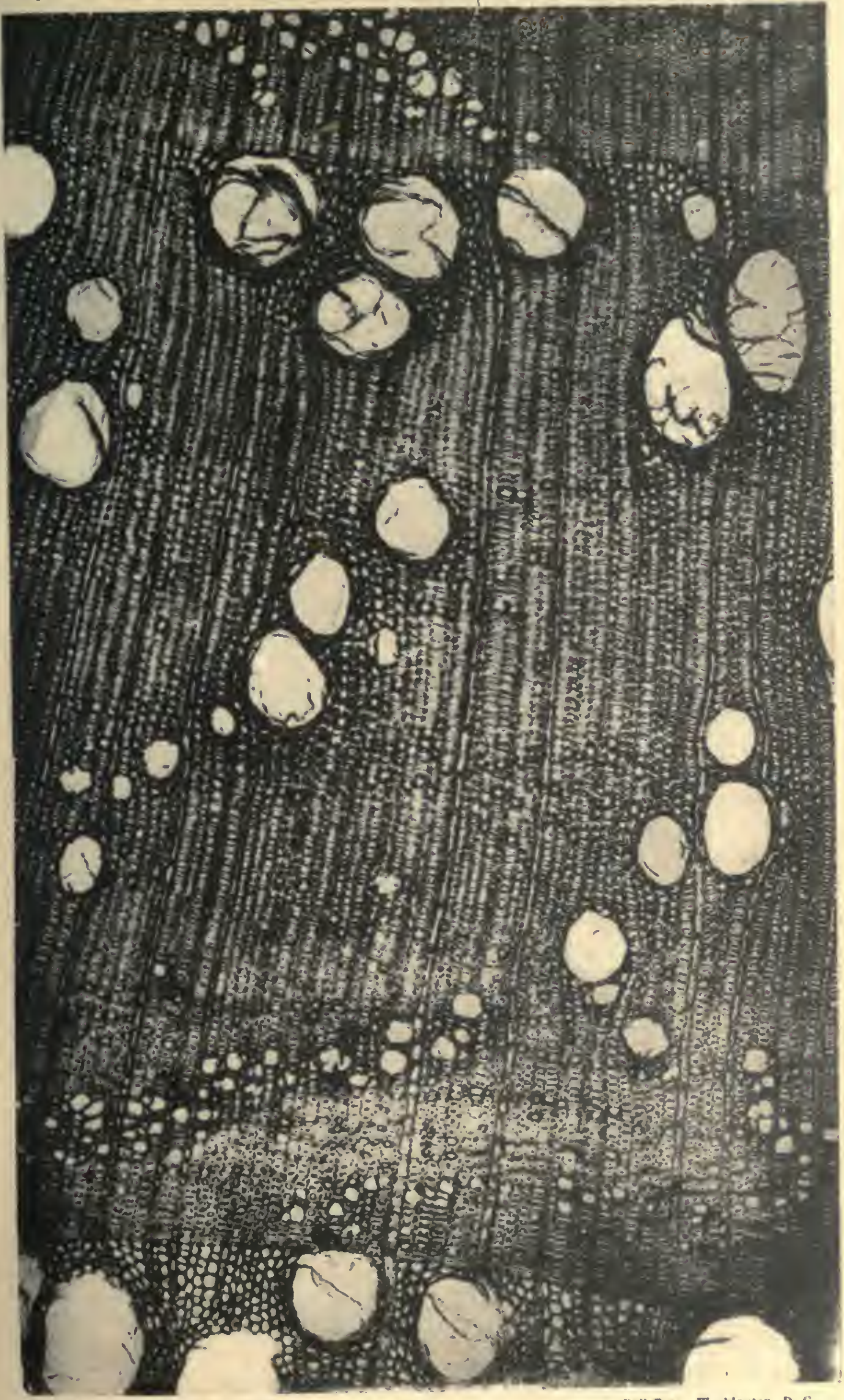
† See foot-note, p. 37.

‡ Prof. Charles H. Peck thinks it cannot be *quercina*, as he has not been able to find any specimens of this species.

CHESTNUT, *Castanea vulgaris*, var. *Americana*, A. D C., No. 290.

Each annual ring of wood, as seen in the photomicrograph of the transverse section, has one concentric circle of ducts, at least in the interior portion of each ring, and in other specimens a second and sometimes a third occurs. Botanists recognize only one species; but in regard to structure and color of the wood two varieties are discernible. In one of the sections, taken from a tree grown near New York City, the effect of climatic conditions upon the character of the cells formed is readily traced.

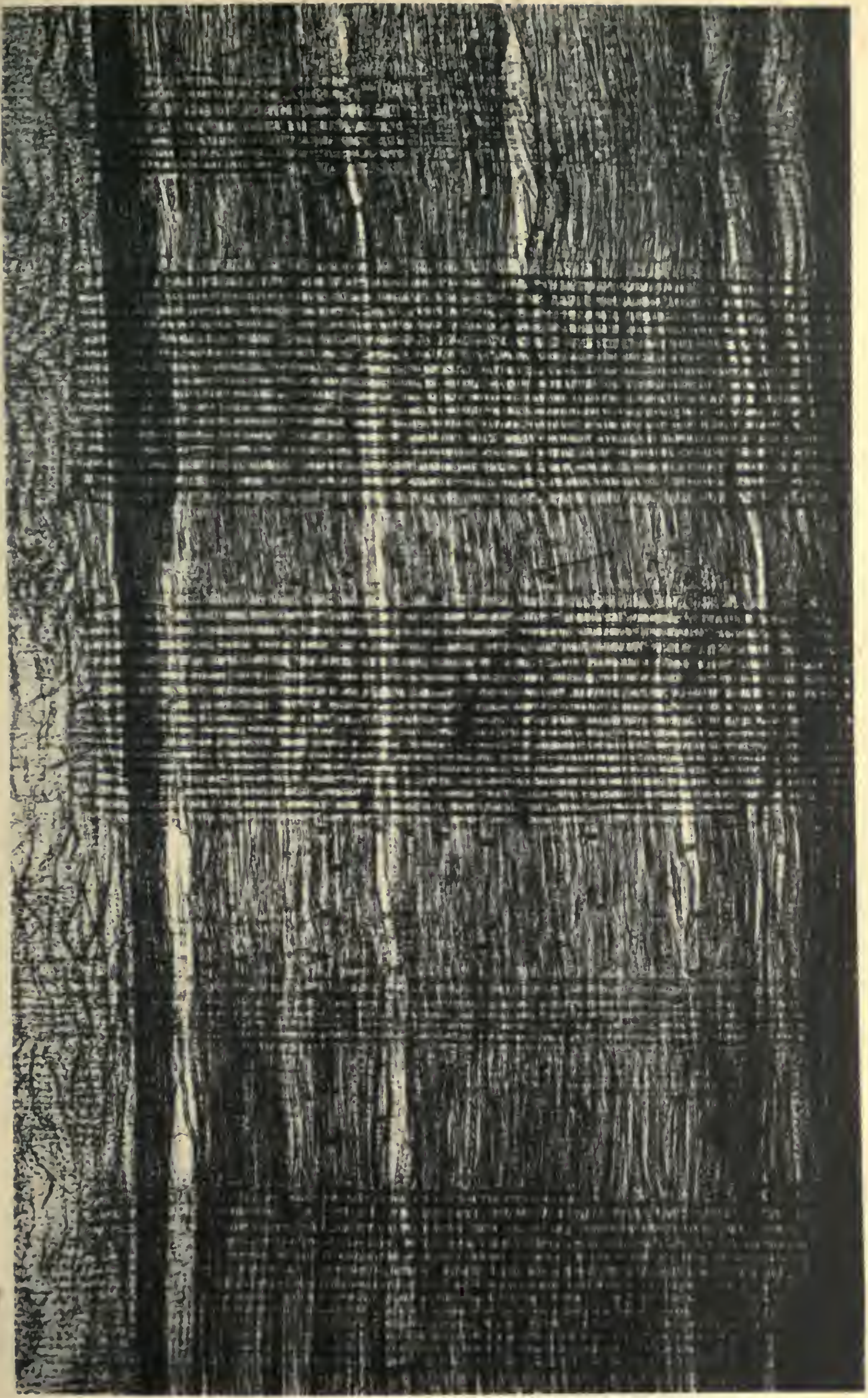
In order to show an entire section of this ring (from the second growth wood, the most desirable for ties) three plates of the size of the one presented (7 by 7½) would be required. The section of this ring was taken from near the heart of the tree, and exhibits the characteristic structure, though the ducts are only about one-third the usual size. The wood from which the photomicrographs of the other sections were taken is most suitable for ties. Surrounding the ducts and growing with them are tracheids, which have a lumen from one-half to two-thirds the size of the cell; but in some of the annual rings (from the same piece of wood) only a few of the tracheids are seen with a large lumen beyond the first row of ducts; there are also found tracheids with a small lumen and some fibers making up the rest of the ring, while in an adjacent ring the tracheids may form many rows beyond the ducts, the wood-fibers usually completing the ring. Wood formed of rings of the latter character is stronger and has a greater specific gravity than wood which is formed of annual rings, as first described. Under the microscope the distinction between the two grades is easily made; for in the wood composed mostly of fibers there are numerous cells, which in the alburnum (except in active growth) contains starch. The heavy lines of cells running down the page represent the medullary rays, which in this wood are mostly in single rows, the cells being placed one above the other. The medullary rays bend around the ducts, their cells being slightly flattened and curved. In the wood-fibers the medullary rays are intersected at right angles by numerous rows of cells which contain starch, as described above. In the radial section the cells crossing the page are those of the medullary rays, while on the left are seen the numerous tracheids which surround the ducts. On the right of the page are the longitudinally arranged wood-cells and traces of some of the smaller ducts. The ends of the medullary rays are seen to be composed of cells in single rows, and very numerous. The cells of this wood contain considerable tannin, and their size, with a comparatively large lumen, shows that the wood has a low specific gravity, ranging from 0.36 to 0.56, the former occurring in large trees grown in dense forests, while the latter is frequently found in small



Photomicrograph by P. H. Dudley. Bell Bros., Washington, D. C.

290. CASTANEA VULGARIS, VAR. AMERICANA, A. DECANDOLLE; CHESTNUT.

Transverse Section x 100 Diameters.

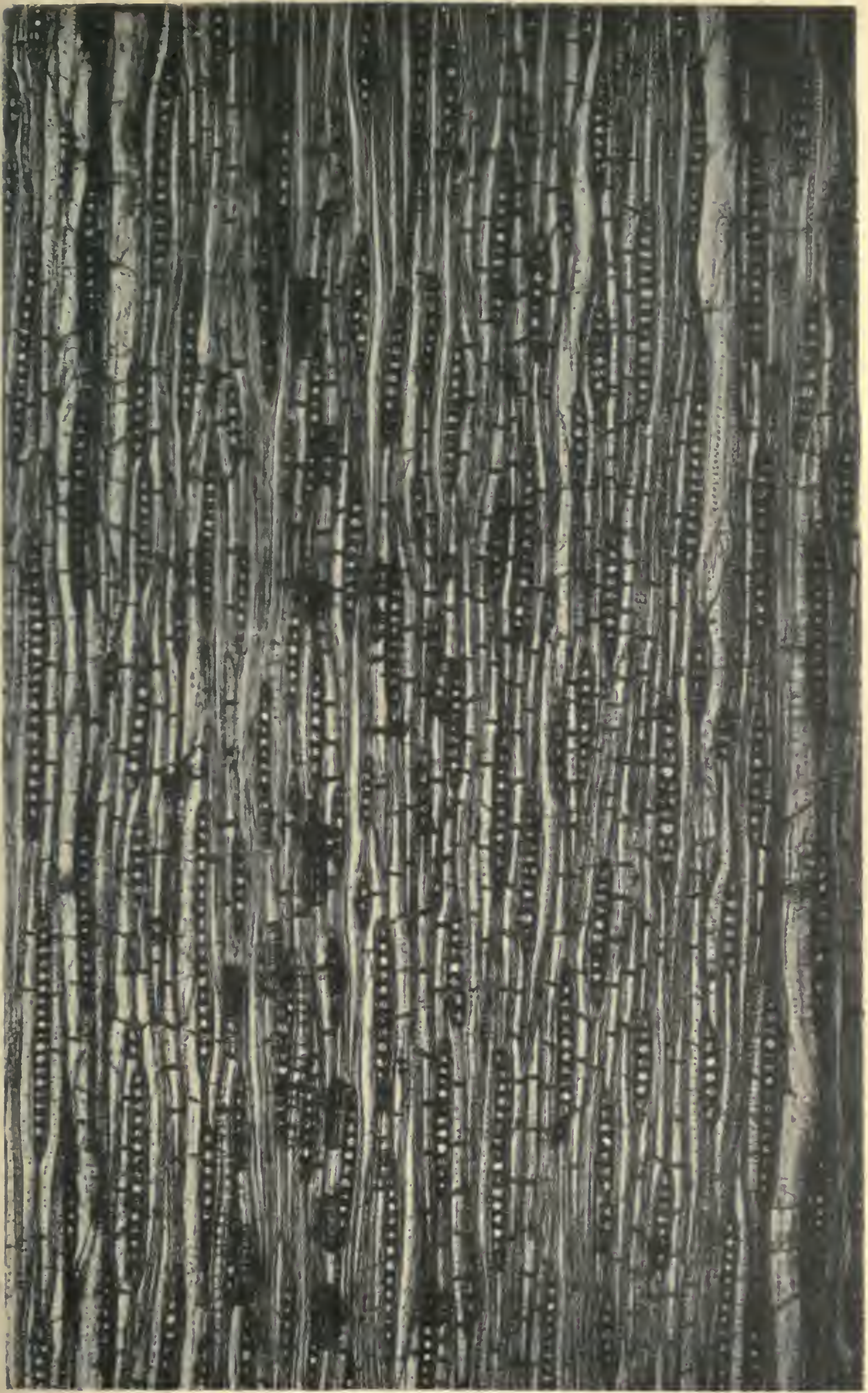


Photomicrograph by P. H. Dudley.

Bell Bros., Washington, D. C.

290. CASTANEA VULGARIS, VAR. AMERICANA; A. DECANDOLLE; CHESTNUT.

Radial Section x 100 Diameters.



Photomicrograph by P. H. Dudley.

Bell Bros., Washington, D. C.

290. CASTANEA VULGARIS, VAR. AMERICANA; A. DECANDOLLE; CHESTNUT.

Tangential Section x 100 Diameters.

trees having large leaf areas and growing in open woods, as second-growth timber.

Change of sap-wood to heart-wood.—In large trees this change takes place in from ten to fifteen years, while in younger trees, growing in the New England States, the change is completed sooner, usually in four to six years. This is important, as the majority of ties are cut from small timber, and flattened only on two sides, the sap wood forming but small portions of the faces of the ties.

Durability of Chestnut ties.—Chestnut wood is far more durable in contact with the soil than any other species considered in this paper, except, possibly, the White Cedar. But as soon as iron comes in contact with the longitudinally arranged fibers of the unseasoned wood, its durability is decreased, and decay is likely to commence, especially around the spikes. After a few years ties of sound Chestnut are found to decay from the surface downward, and rapidly in the vicinity of the spikes and under the rails. In most soils, if the ties remain in the track over six or eight years, the ends and central portions above the ground become affected, while the portions under the ballast are sound. The order of decay is the reverse of that of White Oak, Yellow Pine, and Hemlock, and the body of the ties lasts longest when fully imbedded in the ballast.

Chestnut is a soft wood, and in ties which have been removed from the track after four to six years' service, on account of cutting under the rails and injuries from spiking, the ends and centers are found so sound that the opinion has been quite general that Chestnut ties do not decay under ordinary service, but that the failure is due to the mechanical destruction of the wood-layers under the rails. After having the opportunity during the past two years of examining many thousand Chestnut ties, removed from the tracks, I find this opinion needs important modification. Cut out a section of a tie which has had four years of service under fair traffic, and incipient decay is found to have commenced in all of the layers which have been loosened, except three or four under and next to the rail, as here the air dries the wood too rapidly for fermentation to be set up at once; but the fermentation which takes place under these layers soon renders the fibers soft and brittle and capable of furnishing but little support to the rails. It is a well-known fact that the rapidity of abrasion increases with the age of service, which would be expected after an investigation. Could we find ties where the injury to the wood-fibers from the spiking did not show, the affected spot would be V-shaped, the included angle being larger for a broad- than for a narrow-faced tie. This effect can be noticed in Figure 1 (page 61), though that of the spike is included on one side, the dark portion representing the injury. In Fig. 2 the injury is shown extending from the spike along the fibers. In Chestnut ties the spikes soon discolor the wood in immediate contact, and after this has taken place fermentation is more easily set up in the discolored wood than in the uncolored portions. The injury to ties of this wood by the spikes is twofold, mechanical and chemical, both favoring decay around the spikes and under the rails. Boring holes for the spikes would add to the durability of Chestnut ties, and without much detriment to the adhesion of the spikes after two or three years of service.

Under traffic as heavy as that of the Boston and Albany Railroad, the Chestnut tie generally fails by the rails cutting into the face; but, excepting at the entrance of the great yards, this does not occur to a marked extent until the fermentation mentioned has taken place around the spikes and under the rails.

When the rings of wood are in a tangential position to the rails they separate by the breaking of the tracheids to a depth of from one to three inches. Those rings which are cut through and present their edges to the surface, separate and become filled with sand, which is crushed into the wood by the passing of trains, and the sand will be found between the third and fourth layers under the rails. In such cases the fibers are between " the upper and nether mill-stone," and are abraded very rapidly, reciprocal action or abrasion also taking place at the base of the rails.

The decay of Chestnut ties is usually very slow, and on ties affected before they are placed in the road-bed the decay is generally upward.

Preserving Chestnut ties.—But few experiments have been made in preserving this wood for ties, on account of its natural durability. Those experiments made with corrosive sublimate hardened the fiber and increased the wearing capacity.

FUNGI.

The fungi which I have found on Chestnut ties in the New England States are as follows:

Polyporus versicolor, Fr.; very common on posts also.
Polyporus hirsutus, Fr.
Polyporus pergamenus, Fr.; on ties with the bark on.
Polyporus sulphureus, Fr.; without doubt very common.
Polyporus spumeus, (?) Fr.; on ties removed from the track.
Agaricus Americana, Pk.
Agaricus sublateritius, Fr.; very common.

WHITE CEDAR, *Chamæcyparis sphæroidea*, Spach. No. 329.

This tree is found from "Southern Maine, near the coast, to Northern Florida, and along the Gulf Coast to the valley of the Pearl River, Mississippi," * reaching a height of 75 to 80 feet, and sometimes with a trunk 3 feet in diameter, generally growing "in deep, cold swamps." *

In the New England States this tree is a very slow grower, in the majority of cases, the annual layers ranging from 1-32 to 1-16 of an inch; some exceed this width, but in several ties measured they did not ex-

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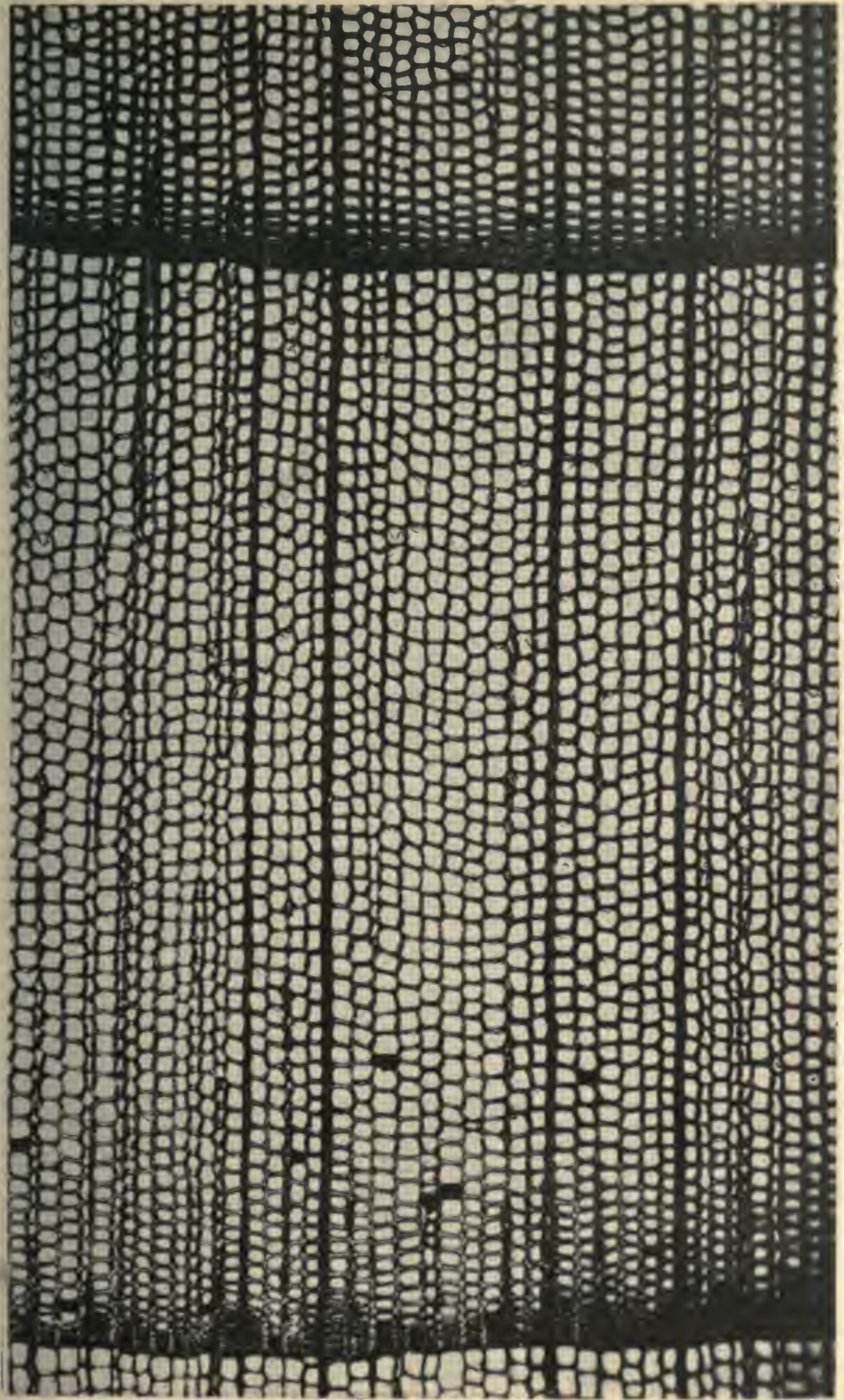
* C. S. Sargent, Vol. IX., Census Report, 1880.

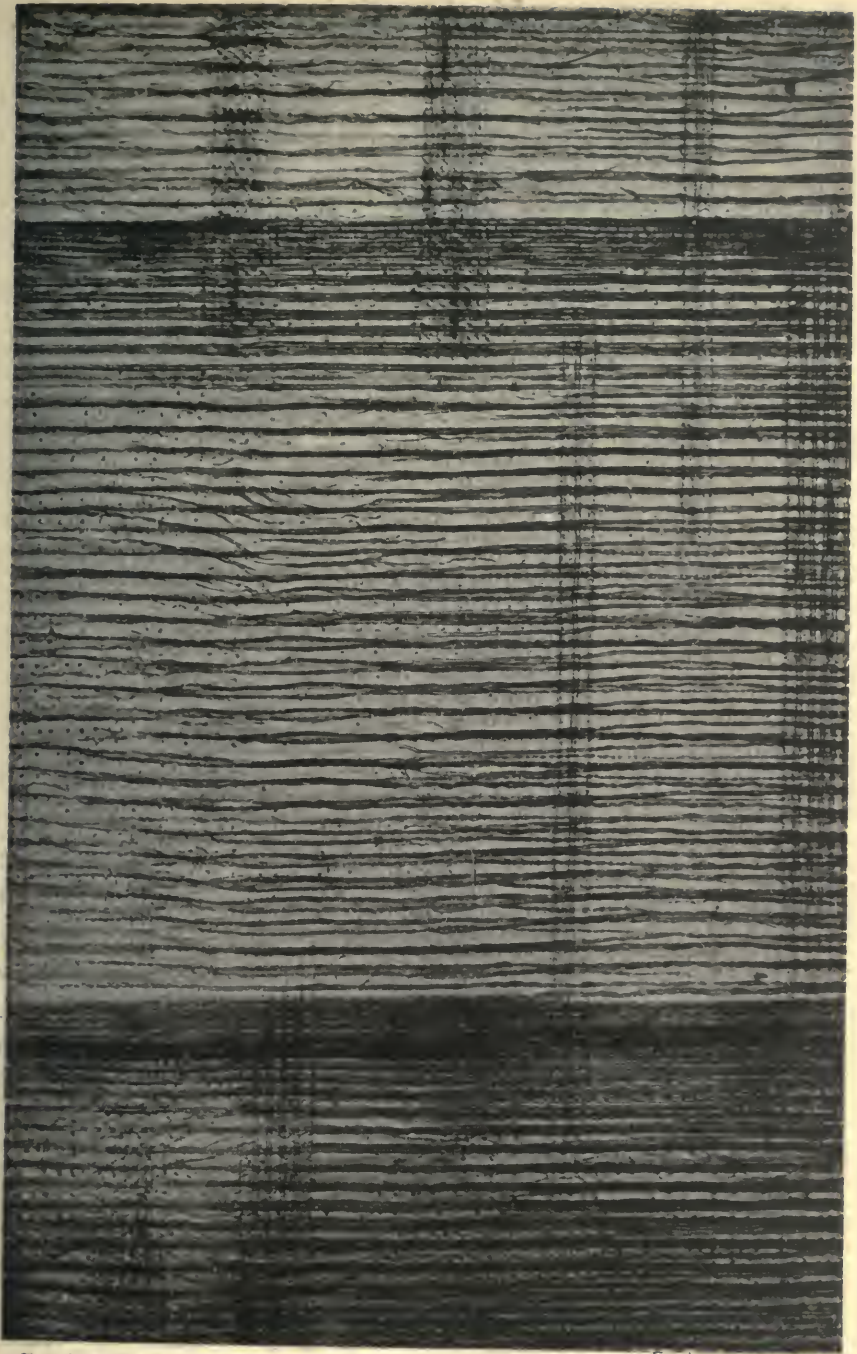


Photomicrograph by P. H. Dudley.

Bell Bros., Washington, D. C.

329. CHAMAECYPARIS SPHAEROIDEA, SPACH.; WHITE CEDAR.

Transverse Section x 100 Diameters.

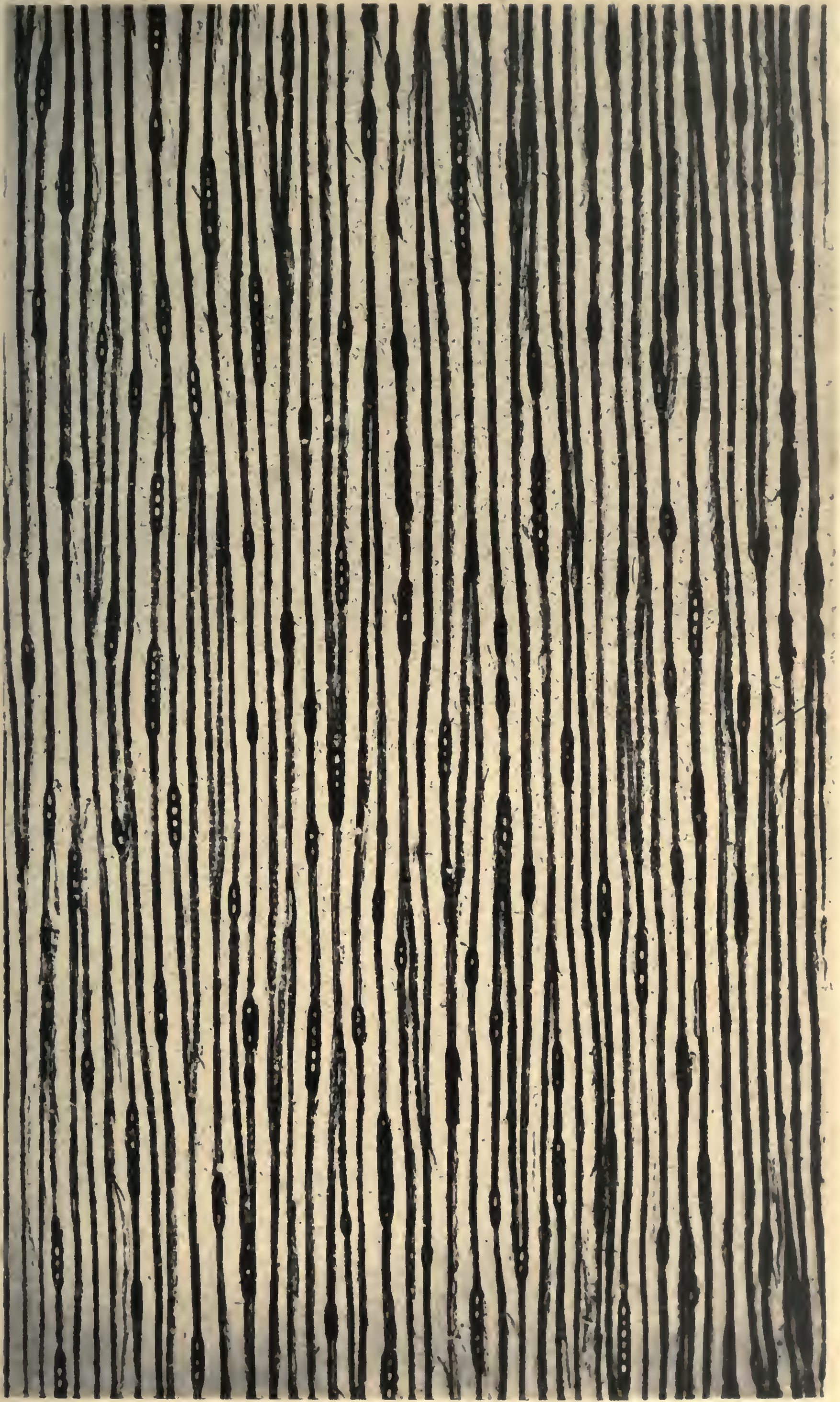


Photomicrograph by P. H. Dudley.

Bell Bros., Washington, D. C.

329. CHAMAECYPARIS SPHAEROIDEA, SPACH.; WHITE CEDAR.

Radial Section x 100 Diameters.



Photomicrograph by P. H. Dudley. Bell Bros., Washington, D. C.

329. Chamaecyparis Sphæroidea, Spach.; White Cedar.

ceed 1-32 of an inch 2 inches from the center. The wood is very light, weighing only from 19 to 22 pounds per cubic foot.*

In the photomicrograph of the transverse section the cells are seen to be of nearly one size throughout the entire layer, being only slightly compressed in the fifth to the tenth row of cells of the latest growth in each ring. The walls of the tracheids are of nearly uniform thickness throughout the ring. In this wood there are no resin-ducts; there are, however, special resin-cells represented by a few black rectangular spots near the outer portion of each ring. This feature is common to all the cedars I have examined, and also to the Sequoias. The diameter of the tracheids is the smallest of any of the Conifers under consideration, being only 0.0013 to 0.0015 of an inch, the lumen ranging from 0.0011 to 0.0013 of an inch. The medullary rays are very delicate, and in this view hardly show a trace of an opening.

The radial section was taken from a specimen of narrower layers than those of the transverse section. The longitudinally arranged cells of the tree are represented horizontally on the page. The lenticular markings are very small and close together, especially near the ends of the cells. The chain-like appearance of the small resin-cells shows for a short distance in the lower annual layer. The cells of the medullary rays, which are not abundant, run down the page, and, being very small and generally filled with resinous products, are not easily affected by fungi. The great delicacy of the medullary system is seen in the tangential section; it is found to be composed of only single rows of cells, which are superimposed one above the other. Often but a single cell is found, yet bundles of two, three, or four cells are very common; those of six are interspersed at great intervals in this section, and now and then a larger bundle occurs. I have found the medullary system to be very delicate in all the cedars, which, in addition to the presence often of resinous matter, perhaps in a measure accounts for the slow lateral spread of the spots of decay in this wood.

The impression made on one who for the first time sees ties of this wood, now being received by the railroad companies, would not be as favorable as that in the case of those who have had a large experience in their use. Out of many thousands which I saw just received by railroad companies this spring, not 10 per cent. were perfectly sound: yet, when put in the ground, they will last from eight to ten years.

Some ties would have a decayed center, while others would have only five to ten small spots; but as long as there was sufficient room for spiking the ties were considered good, as they decay in the ground so slowly that their mechanical destruction under the traffic is accomplished before they are completely rotted.

From its great durability this wood is well adapted for railroads of moderate passenger and freight traffic. The ties with a 7- to 8 inch face, 7 inches thick and 8 feet long, have this spring cost from 30 to 35 cents, while Chestnut ties of the same size cost 55 to 65 cents in the vicinity of

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* See Table II., Specific Gravity, p. 53.

Boston, Mass. The sap-wood on the ties is only one-half to three quarters of an inch thick, and quite generally the former. Sixteen or seventeen of these ties are put under a rail 30 feet long. It is the softest and lightest of all the woods considered in this report, but it is found to be most durable in service, and, because of its small medullary rays, when in the ground does not absorb proportionately as much water into its wood-cells as the Hemlock or Chestnut, and after three or four years' service is not cut into as rapidly as are the two latter kinds of ties. The logs of this wood which have been buried in the swamps of New Jersey for hundreds of years, when cut, rise and float, showing that they are not " water-logged."

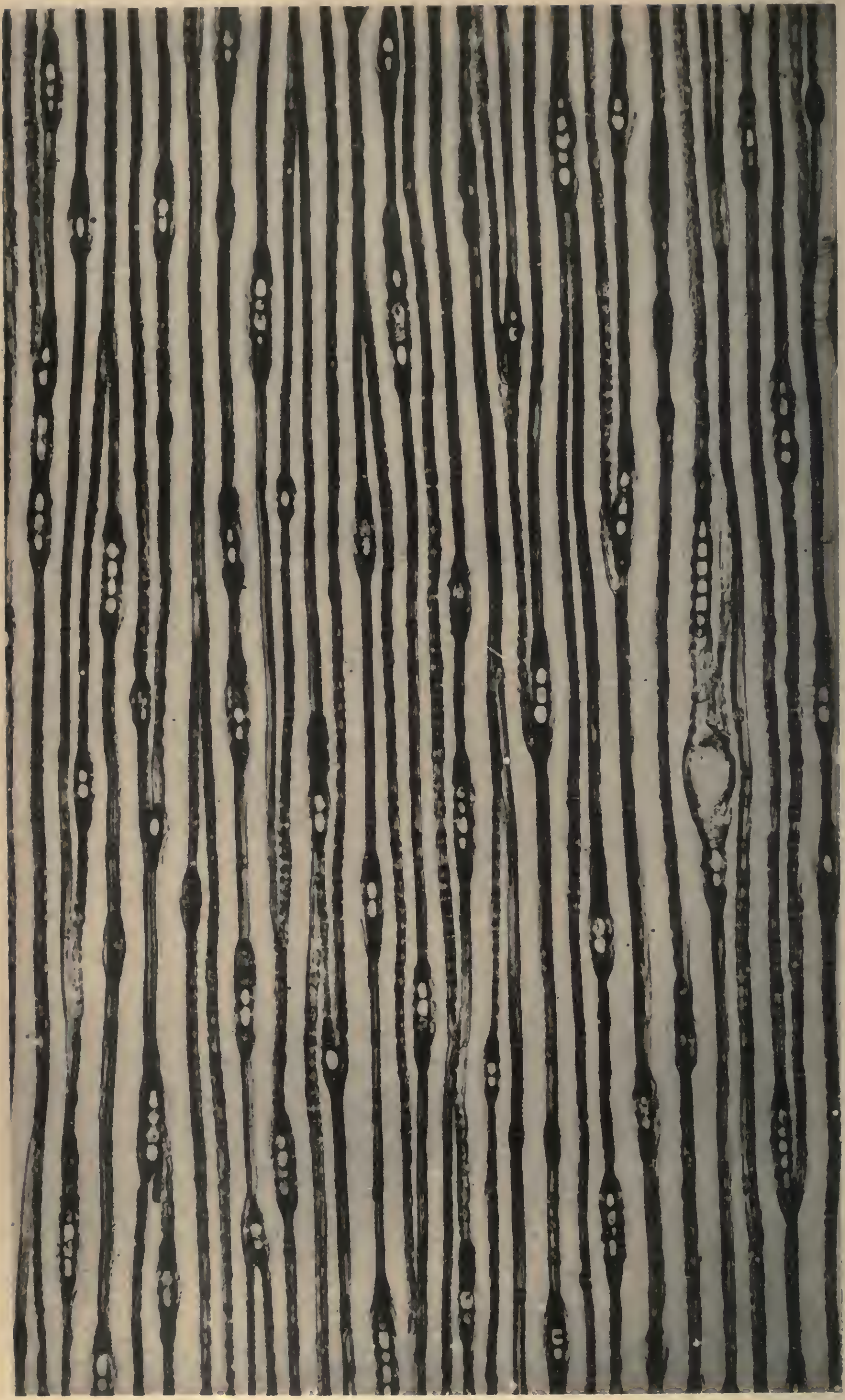
This tree has an abundance of small limbs which shoot out near the ground and do not die until the limbs and foliage above them shut out the necessary supply of light for growth; then they become dry, but do not decay rapidly; when they break off it is close to the trunk, the wound being healed over at once, as in many other trees; but it requires from ten to thirty years to close over the projecting stub.

In many cases spores of higher fungi (*Hymenomycetes*) and the *sporidia* of some species of the *Sphæriacei* find lodgment on the bark of the broken limbs, and finally a growth is extended to the heart-wood. But on account of limited supply of air the decay thus set up is very slow, and it follows up and down the wood-cells, spreading laterally very little. Thus the decayed tissue may extend considerable distance in the timber and yet not exceeding one-half or an inch in diameter. If the wound finally becomes closed and the air supply cut off, all fungous growth is checked, if not fully arrested.

Durability.—On account of its softness and natural durability, this wood has not been treated to any extent to preserve it for ties. The spikes do not hold in it as well as in some of the harder woods, yet it is very valuable for the above-mentioned traffic, and its use is on the increase. The rings do not separate as freely as those of the Yellow Pine, and the cutting down of the fibers is due largely to abrasion; the spikes draw, and from the looseness of the rails, together with the sand and grit between them and the ties, the fibers are crushed by the passing of every train. Could the rails be kept tightly spiked, the cutting would not proceed so rapidly. For a trunk-line freight traffic the White Cedar tie is too soft for the present 65-pound rail with only a 4¼- to 4½-inch base. In order to save the Chestnut ties for their curves, roads of light traffic are now commencing to replace these on their tangents with Cedar.

FUNGI.

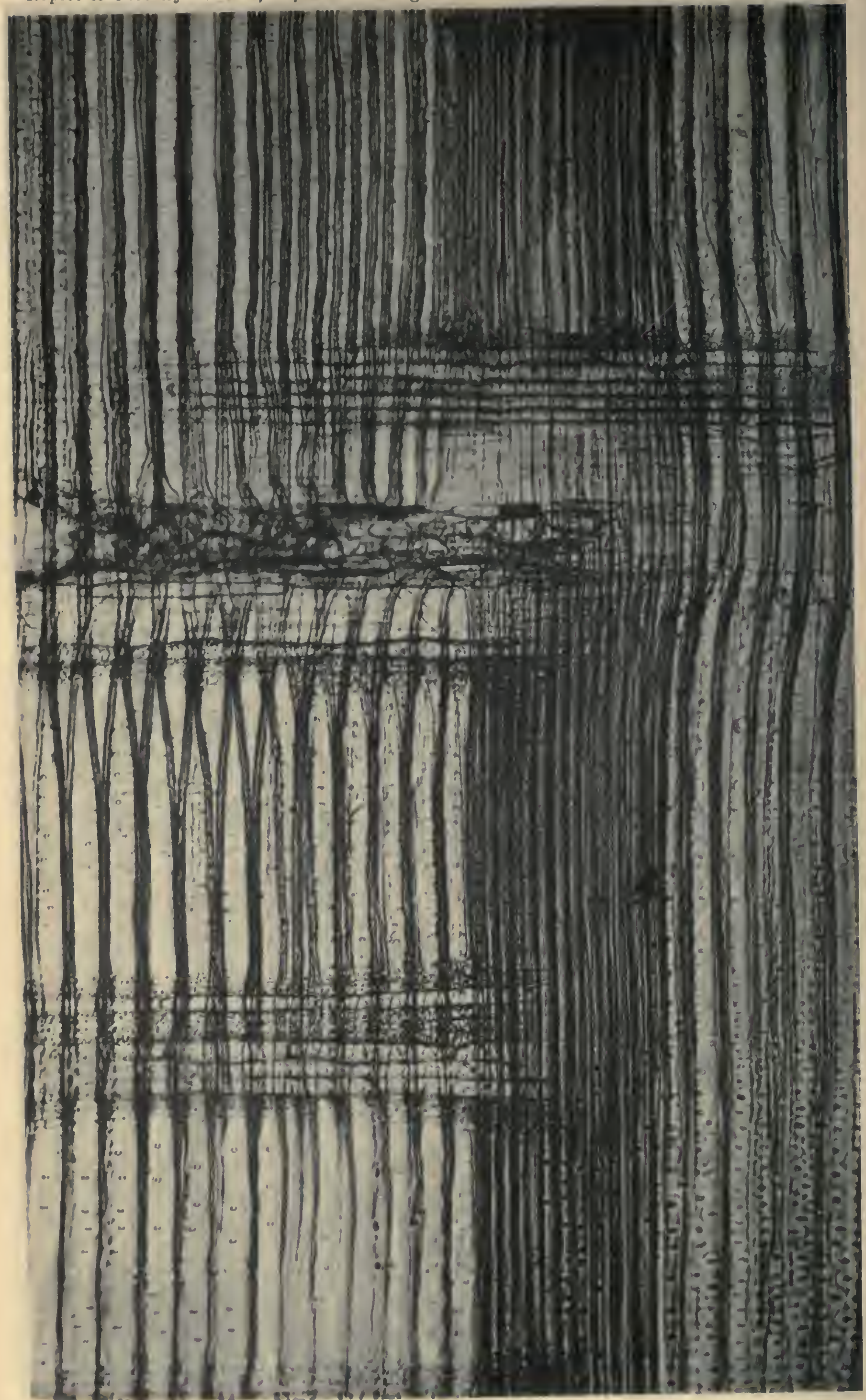
The species of fungi that attack this wood are but little known. In searching for them on the Boston and Maine Railroad, from Boston to Portland, I found specimens in fruit of only *Agaricus campanella*, Batsch , which has a tawny pubescence at the base. *Agaricus melleus* Vahl., has been said to attack this wood, but I have never been able to find it either on the prostrate trunks or on the ties.



Photomicrograph by P. H. Dudley. Bell Bros., Washington, D. C.

380. PINUS PALUSTRIS, MILLER; LONGLEAVED PINE.

Tangential Section x 100 Diameters.

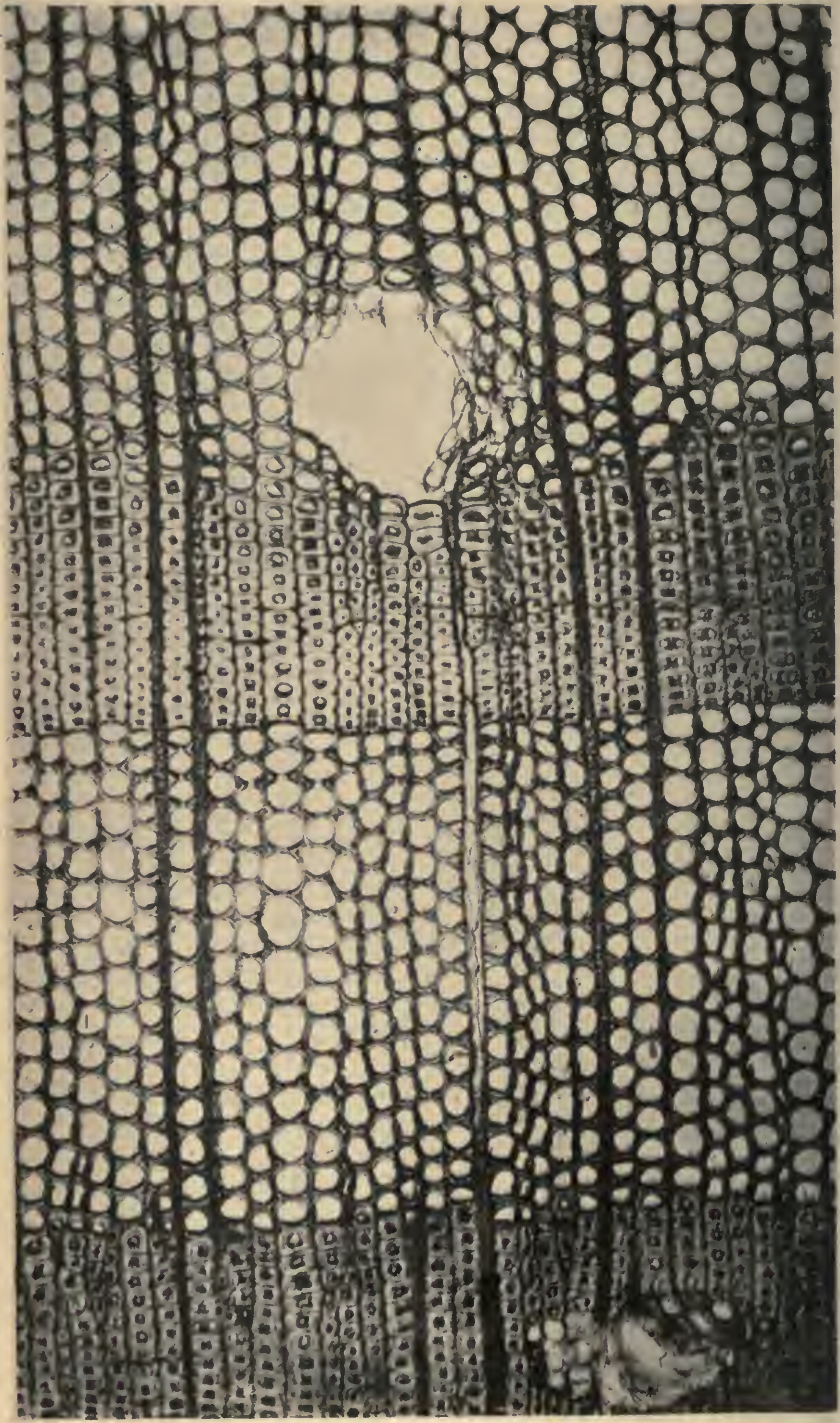


Photomicrograph by P. H. Dudley.

Bell Bros., Washington, D. C.

380. PINUS PALUSTRIS, MILLER; LONGLEAF PINE.

Radial Section x 100 Diameters.



Photomicrograph by P. H. Dudley.

Bell Bros., Washington, D. C.

LONG-LEAVED OR YELLOW PINE, *Pinus palustris*, Mill. No. 380.

The striking appearance of the structure of this wood, as seen in the transverse section, consists in the strongly marked zones of different cells in each layer of growth. At the present time satisfactory distinctive names have not been given to these two classes of wood-cells or tracheids. I shall use the term thin- and thick-walled tracheids to distinguish them. The former grow in the first part of the season, and the latter during the summer; but the line of demarkation between them is sharp, not being a gradual merging as in most of the other Conifers. In some trees, each layer is made up of about equal portions of the thin- and thick-walled tracheids, though these layers may vary in thickness from one-thirty-second to one-fourth of an inch; in other trees, the layer of thin-walled tracheids is the thickest, and, as a rule, such wood is of less specific gravity than that with thicker layers. The size of the wood-cells in different individuals is not the same, and this feature also affects the specific gravity.

In selecting a piece from which to make an illustration to show an entire annual ring, we are obliged to take one of less than medium thickness in order to get it on the page. In a luxuriant growth a larger one might be selected which would show only one class of tracheids. Measurements from these photomicrographs will give average results for this wood. The largest of these walls measures .003 by .0025 of an inch, with a lumen of .0025 by .002 of an inch; the thick ones are .002 by .001 of an inch, with a lumen of .0006 by .0004. Many rows of cells of the same size are seen running parallel to the medullary rays, usually single, sometimes double, but rarely in threes.

The thick-walled tracheids are nearly quadrangular, and some of them tabular, and the same number of concentric rows occupy only about one-half as much in width of the ring as would the same number of rows of thin-walled tracheids; the former give the hardness and great elasticity to the wood. It has been generally stated that the thick-walled tracheids contain the most of the resinous matter; this applies only to the volume, as by weight I found that practically they contain equal amounts. The large openings which inclose the tissue of the resin canals are prominent features in the transverse section of this wood. Smaller canals occur in the medullary rays, and if they were wider they could be readily traced in the illustration; one appears in this photomicrograph. The two systems of resin-canals are connected.

The heavier lines of cells running up and down the page are the medullary rays with their canals; and, though numerous, the cells are not strong, the annual rings of wood being quite easily separated from each other when under severe service, or in the sun. Thick layers can be readily separated with a knife, from sections one-half to three fourths of an inch in width. The separation of the thick- from the thin-walled tracheids in the same layer is far more difficult, the latter breaking off in short sections.

The lenticular markings on the tracheids are more abundant near the ends of the cells than in the center, and the appearance of swellings on the walls of the smaller cells, parallel to the medullary plates, is due to the cross-section of the lenticular markings.

The walls of each cell are composed of three layers—an inner one, quite thin and surrounding the lumen; then a thick one, and, lastly, a thinner one, which is so delicate that between the adjacent cells it appears as one wall; but, in some woods, is known to consist of two different layers for each cell and is believed to be so in all; its division can be seen in the transverse section of the Tamarack.*

In the radial section the longitudinally arranged cells are seen with their lenticular markings. It is generally stated that in the duramen the lamella between the domes of each one of these markings becomes broken, so that there is a free communication between the cells; this is not the case: the delicate membrane is pushed over to one side in the direction of the exit of the sap, and may be found by the highest grade of objectives. When it is covered with resinous products the passage of heavy fluids is much impeded and this is one of the reasons why, without special treatment, it is so difficult to secure the penetration of preserving fluids in this wood. These cells can be filled with any antiseptic (creosote combined with an oil, etc.), but it is a question of time, heat, and vacuum.

The walls of the more open or larger cells are seen to be some distance apart; the white space shows their cavities, with the lenticular markings appearing in the background as it were, or in this class of tracheids in plains parallel to those of the medullary rays. The dark upright bands shown in the photomicrograph represent the thick walled tracheids. The lenticular markings in these are generally on the walls which lie in planes at right angles to those of the medullary rays and are much smaller in diameter. The lines crossing the page represent the medullary rays, the upper one showing a resin-duct in longitudinal section, the cells of which are very delicate. The marginal cells of the medullary rays are decidedly irregular, and are more or less serrated; the center rays have two to four thin places opposite each cavity of the tracheids; but in the transverse section, where the latter are in contact with the medullary rays, it can be seen that the inner and next lamella are not continuous; the same feature occurs in the White Pine.

In the tangential section are seen the openings of the medullary rays, which, except those inclosing the resin canals, are of single rows of cells, one to eight being superimposed one above the other in the bundles; the marginal cells are the darker spots above and below the central portion of each bundle. In these sections the lenticular markings are seen to be very abundant on the cell-walls. The interlacing of the tracheids is also well shown. On the right is seen an opening of a resin-canal in the medullary system. In the duramen the medullary cells are more or less filled with resinous products, which makes it difficult to force fluids through these rays into the central portion of the stick; and in the ground, too, the moisture penetrates longitudinally much faster than in an opposite direction through the medullary rays. As before stated, the cells of the medullary rays are not strong; in all cases spiking the ties separates each layer longitudinally from three-fourths to one inch on each side of the spike, and in many ties the checks extend much farther.

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* See transverse section *Larix Americana*, p. 51.

DURABILITY AND FUNGI.

Ordinary specimens of Yellow Pine contain from eighteen to twenty per cent. of resinous matter, which is supposed to add much to the durability of the wood. But this does not seem to be the case when the wood is put in the ground, or in the road-bed as ties. In such situations it is rapidly destroyed by the fungus *Lentinus lepideus*, Fr., an Agaric. I have found this so general over a great extent of territory that I am inclined to think it is a fungus peculiar to the heart-wood of this timber, especially when the latter is in exposed situations. I have found *Trametes pini*, Fr., on dock-timbers a few times, but more often on ties. The mycelium of the latter is yellowish, a color that distinguishes it from the clear white mycelium of the former fungus. Long-continued warmth and moisture facilitates the growth of the mycelium of *Lentinus lepideus*, and, consequently, rapid destruction of the wood. I have samples of Yellow Pine ties from the Panama Railway which were rotted in two years, while in the Southern States they last from four to six years; in the Middle States, from five to eight years. Formerly the first Yellow Pine ties used on the New York railways lasted from ten to fourteen years. The reason given why the present ties do not last longer is that they are now made from timber of "tapped" trees. This, however, is not the sole reason, especially in road-beds where Yellow Pine ties were formerly used, and where the mycelium of its injurious fungus remains from former decayed ties in the road-bed and is ready to attack the new summer-laid ties. The rational procedure from these observations would be, to replace the unsound ties by such of another wood as are not affected by the same fungus.

When the Yellow Pine wood can be kept comparatively dry, it is very durable; this is shown by the ties not decaying quickly where the upper surface remains dry, but still does not always indicate what has taken place on the inside or underneath. Upon raising the track, many unsound ties are found, which on the surface did not indicate the presence of decay. In the vicinity of Albany, N. Y., Yellow Pine ties in cinder ballast (from locomotives) are rotted by their specific fungus much faster than they are in gravel ballast. As before stated, the layers of wood are checked in driving the spikes, and, moisture thus being admitted, fermentation takes place and the layers separate under the rails, frequently throughout the entire length of the tie. The mycelium of *Lentinus lepideus* often follows the checks, and the decay is thus hastened.

Under severe service it is not uncommon to see the ends of many ties of this wood split and crushed, offering but little support to the rails, with the spikes loose. The fermentation, which precedes the growth of the fungus mentioned, softens the thin-walled tracheids first; then often larvæ, from one-sixteenth to one-eighth of an inch in length, bore through and through the softened cells, while the harder tissues are left undestroyed until the decay is farther advanced; and thus what seems to be a sound tie from above, is but a series of shells. *Sphæria pilifera* (Fr.) grows in great abundance on the sap-wood of Yellow Pine, discoloring the wood with its dark threads. The abundance of the *perithecia*[*] of this fungus on sawed lumber gives the surface a dark moldy appearance; drying, however, checks the growth, but it is again set up as soon as moisture and warmth are present, and, if the timber be still unaffected, these same conditions will be favorable to fermentations and the consequent decomposition of the sap-wood. This is readily noticed in the floors of freight-cars, the sap-wood rotting in one or two years; thus it would seem advisable never to use sap-wood in situations where heat and moisture are liable to occur.

Preservation.—Creosote and other antiseptics can be made to penetrate the heart-wood only quite slowly, so that in many cases the resulting treatment is rather superficial. A recent examination of several thousand cubic feet of timber of this wood, which had been creosoted, showed this to be the case, a superficial exterior protection only. In several places the fungus *Trametes pini* (Fr.) was growing on the wood as though it had not been treated, the mycelium having developed under the superficial coating. In this case the treatment was too short, resulting in a penetration only of one-eighth to three-sixteenths of an inch in depth. I have examined many ties treated with creosote, where the penetration was ample to protect them, showing that the treatment can be such as to thoroughly impregnate them, but it is a matter of time and pressure. I have also examined many of the so-called "vulcanized" ties, which, after three years of service, did not show any decay. It may be, however, that seasoning of the ties of this wood is, on the whole, a matter of first importance to insure longer life.

HEMLOCK, *Tsuga Canadensis*, Carrière. No. 387.

This wood, once very abundant, and still covering a large tract of country, has been extensively used for ties, and will of necessity be substituted for other woods which are now becoming scarce. Professor Sargent,[†] gives its distribution as follows:

> "Nova Scotia, Southern New Brunswick, valley of the Saint Lawrence River to the shores of Lake Temiscaming, southwest to the western border of Northern Wisconsin; south through the Northern States to New Castle County, Delaware, Southeastern Michigan, Central Wisconsin, and along the Alleghany Mountains to Clear Creek Falls, Winston County, Alabama (Mohr.)."

The photomicrograph of the transverse section indicates that the wood is soft, though harder than that of the White Cedar. The zone of thick-walled tracheids in the outer portion usually forms from one-fifth to one-fourth of the ring; where the two classes of cells join in the

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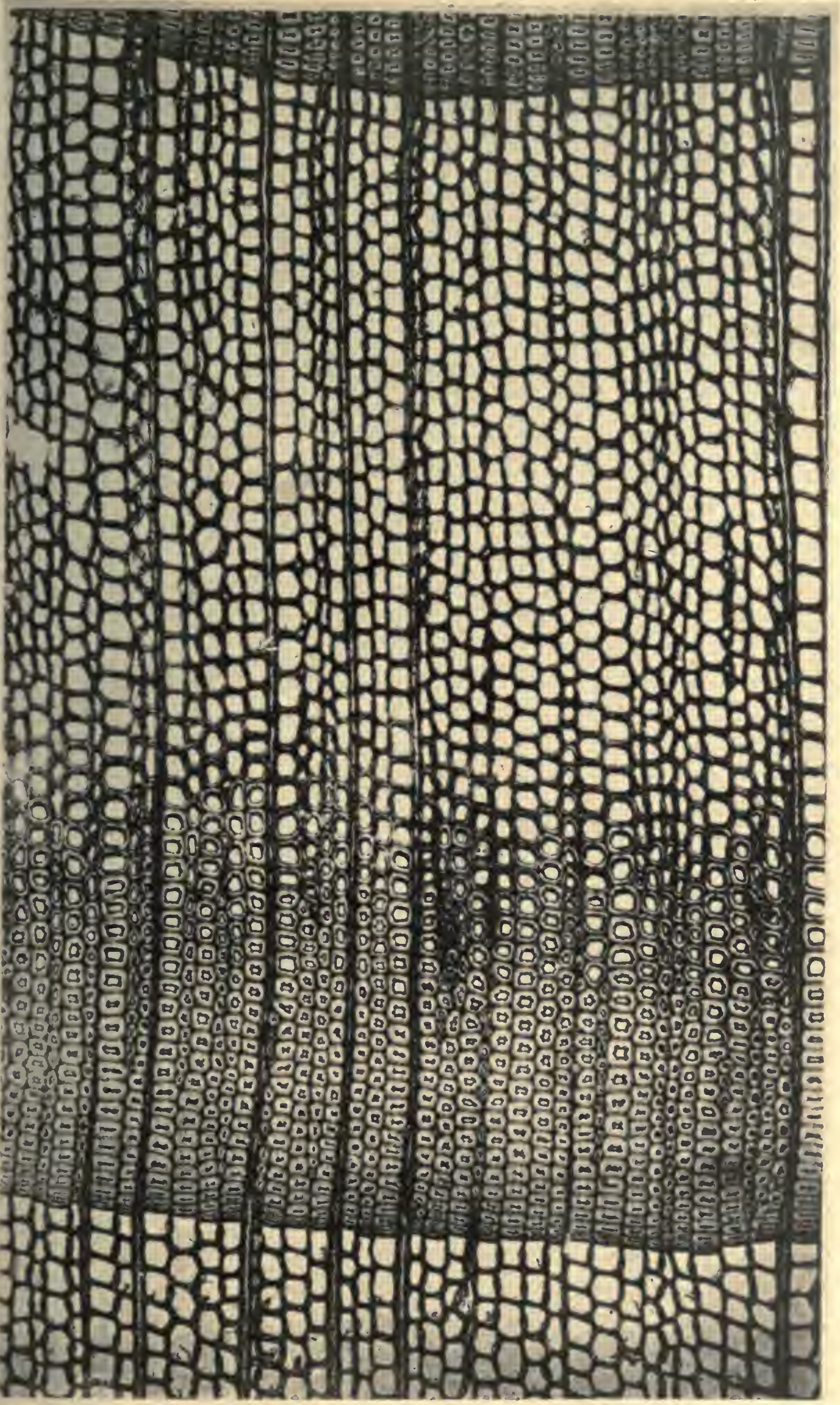
[*] Beak-like protuberances containing spores.

[†] "Forest Trees of North America," Vol. IX. of Tenth Census Report, 1880.

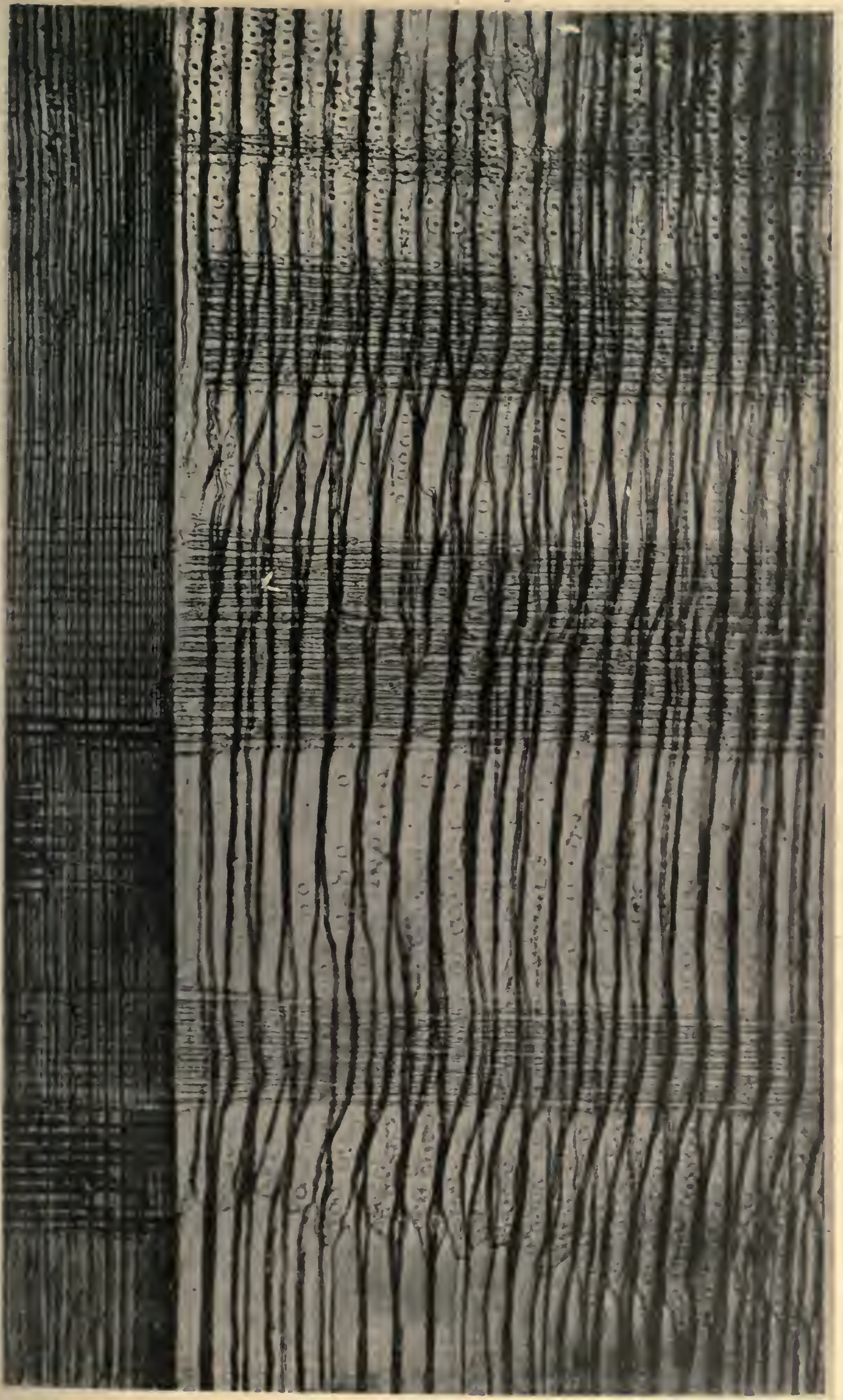


Photomicrograph by P. H. Dudley.

Bell Bros., Washington, D. C.

387. TSUGA CANADENSIS, CARR.; HEMLOCK.

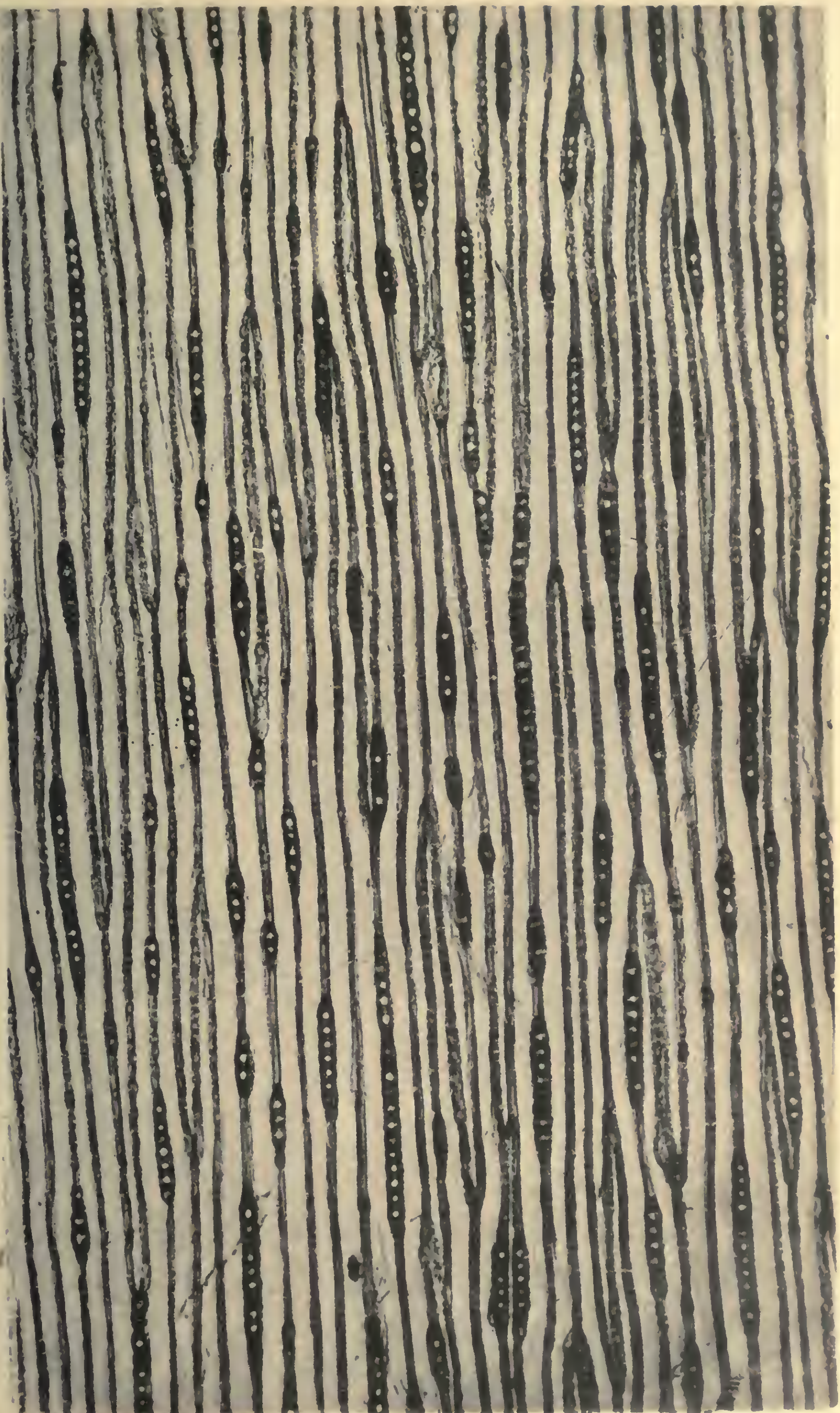
Transverse Section x 100 Diameters.



Photomicrograph by P. H. Dudley. Bell Bros., Washington, D. C.

387. TSUGA CANADENSIS, CARR.; HEMLOCK.

Radial Section x 100 Diameters.



Photomicrograph by P. H. Dudley.

Bell Bros., Washington, D. C.

387. Tsuga Canadensis, Carr.; Hemlock.

same ring there is a gradual merging and not a sharp line of demarcation, as in the Yellow Pine (*Pinus palustris*) or in the Tamarack (*Larix Americana*). The thick-walled cells in this wood are of a different character from those of the two woods just mentioned; the cells are not as strong, the lumen being proportionately larger. The thin-walled tracheids, though not so large as those of the Yellow Pine, are generally quadrangular, and have the same proportionately large lumen, and the corners of the cells not being thickened they are crushed more easily. Like the thin walled ones of the Yellow Pine, both classes of tracheids are "brash," and in breaking snap off quite short. So far as I have observed, the so-called "Yellow Hemlock" has a greater proportion of thick-walled tracheids in each layer than the "White Hemlock."

The lines running down the page represent the medullary rays, and occur only in lines of cells of single width. The absence of resin-canals in this wood is in marked contrast to the Yellow Pine or Tamarack.

In the White Cedar the dark and apparently solid cells shown in the transverse section are those of the longitudinally-arranged special resin-cells; but none of these have as yet been found in the Hemlock, the resinous matter in this wood being much less abundant than in the other Conifers considered. In the transverse section what appears as small cells are those cut off near their tapering ends, and the swelling of the walls on the side in a plane parallel to that of the medullary rays is due to the cross-section of the lenticular markings; in the radial section these will be seen to be smaller and rounder than those of Yellow Pine or Tamarack, but larger than those of the White Cedar. For a long time it has been the opinion that in the mature cell there is a free opening in the lenticular markings, the middle lamella breaking away. This is not found to be the case when examined with the highest grade of objectives. In the large cells the lamella becomes crowded to the opening of the dome on the side where the sap is making its exit, and must be looked for with great care, while in some of the thick-walled cells it retains its central position and is readily seen. In the radial section the structure of the longitudinally-arranged cells is clearly shown, the harder, dense portion of the ring being seen on the left of the page. The lines running across the page represent the medullary rays. Above the upper row are seen the ends of the tracheids slightly rising as they approach the outer portion of the ring.

In the tangential section the ends of the medullary rays are seen to be in single rows, the cells being superimposed one above the other. In a few instances only a single cell occurs, while in others there are two, three, and as many as twenty. These cells, as seen in the radial section, are short and easily parted, not binding the wood together firmly, as in the White Oak. The lenticular openings are abundant on the cell-walls parallel to the medullary plates.

Durability.—The Hemlock is not a durable wood in contact with the ground, and ties decay in about four years. The structure of the wood readily admits of treatment by antiseptics, but it must be thoroughly done; such a treatment that practically will keep every fiber of the wood dry; or, if not thus protected, the antiseptic must be of sufficient strength to prevent any fermentation from being set up. A portion of the wood left unprotected and put in the ground would still be liable to attacks, and decay would soon follow in other parts. Mere exterior protection is one of the best ways to start internal decay, the so called "dry-rot," as timber does not decay unless moisture is present. We have an abundance of proof that Hemlock ties well treated will last for fifteen or twenty years. I have a piece of Hemlock wood which was "Kyanized" in 1847, and has been in the ground until this year, 1886, and is generally sound. The experience of railroad companies in using treated Hemlock ties is so extended in this country that the efficacy of such a plan no longer admits of doubt as to its practicability or expediency. On the Chicago, Rock Island and Pacific Railroad some "Burnettized" Hemlock and Tamarack ties were put in the road-bed in 1866, and in 1882, after sixteen years of service under heavy traffic near Chicago, about 75 per cent. of them were still in the track, and the rails not cutting into them any more than they would into White Oak ties. Several other roads have had similar results. Since 1881 the Eastern Railroad, of Massachusetts, has "Kyanized" (by a simple bath in a 1-per cent. solution of an antiseptic) many thousand Hemlock ties, at a reported cost of 11 to 12 cents per tie, and they are employing the process at the present time. Treating Hemlock by either of the processes mentioned hardens the fiber of the wood. Effective creosoting preserves the timber, but does not harden the fiber as do other treatments. Charring the exterior of Hemlock, as is done for some woods in France, would be but a partial protection, as fermentation might still take place internally.*

FUNGI.

The fungi that attack this wood are numerous, and the following is a list of those so far observed:

Agaricus meleus, Vahl.
Agaricus campanella, Batsch.
Agaricus porrigens, Pers.
Agaricus succosus, Pk.
Agaricus rugosodiscus, Pk.
Agaricus epipterygius, Scop.
Paxillus atrotomentosus, Fr.
Lenzites sepearia, Fr.
Stereum radiatum, Pk.
Polyporus lucidus, Fr.
Polyporus benzoinus, Fr.
Polyporus epileucus, Fr.
Polyporus Vaillantii, Fr.
Polyporus subacidus, Pk.
Polyporus medullapanis, Fr.
Polyporus pincola, Fr.
Polyporus abietinus, Fr.
Polyporus borealis, Fr.

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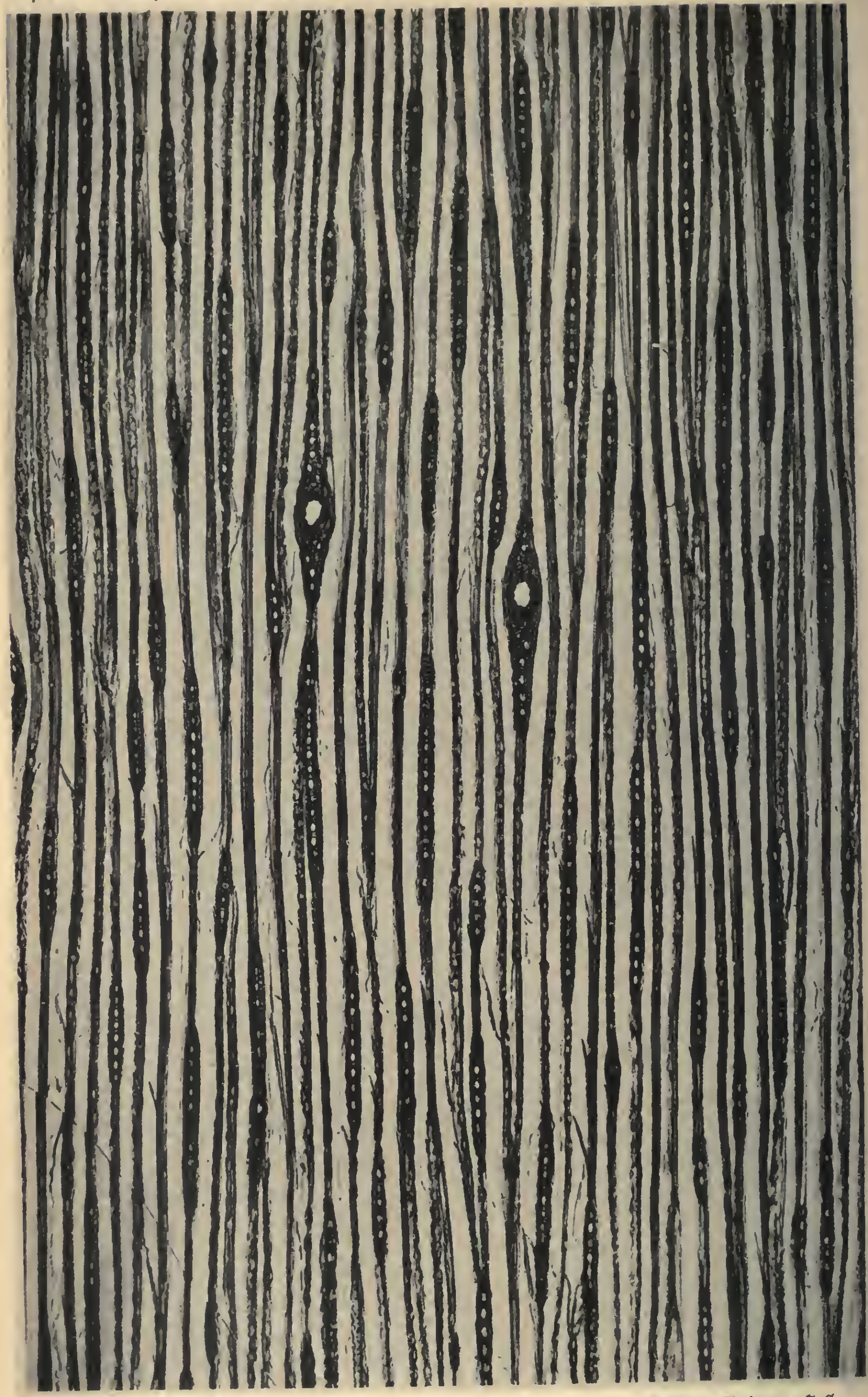
* Since writing the above I have obtained a piece of one of the ties "Kyanized" by the Eastern Railroad Company, put down in 1881 and taken up in the fall of 1886; it is perfectly sound, and, while under very heavy traffic, the wood is not cut into over three-eighths of an inch under the rail.

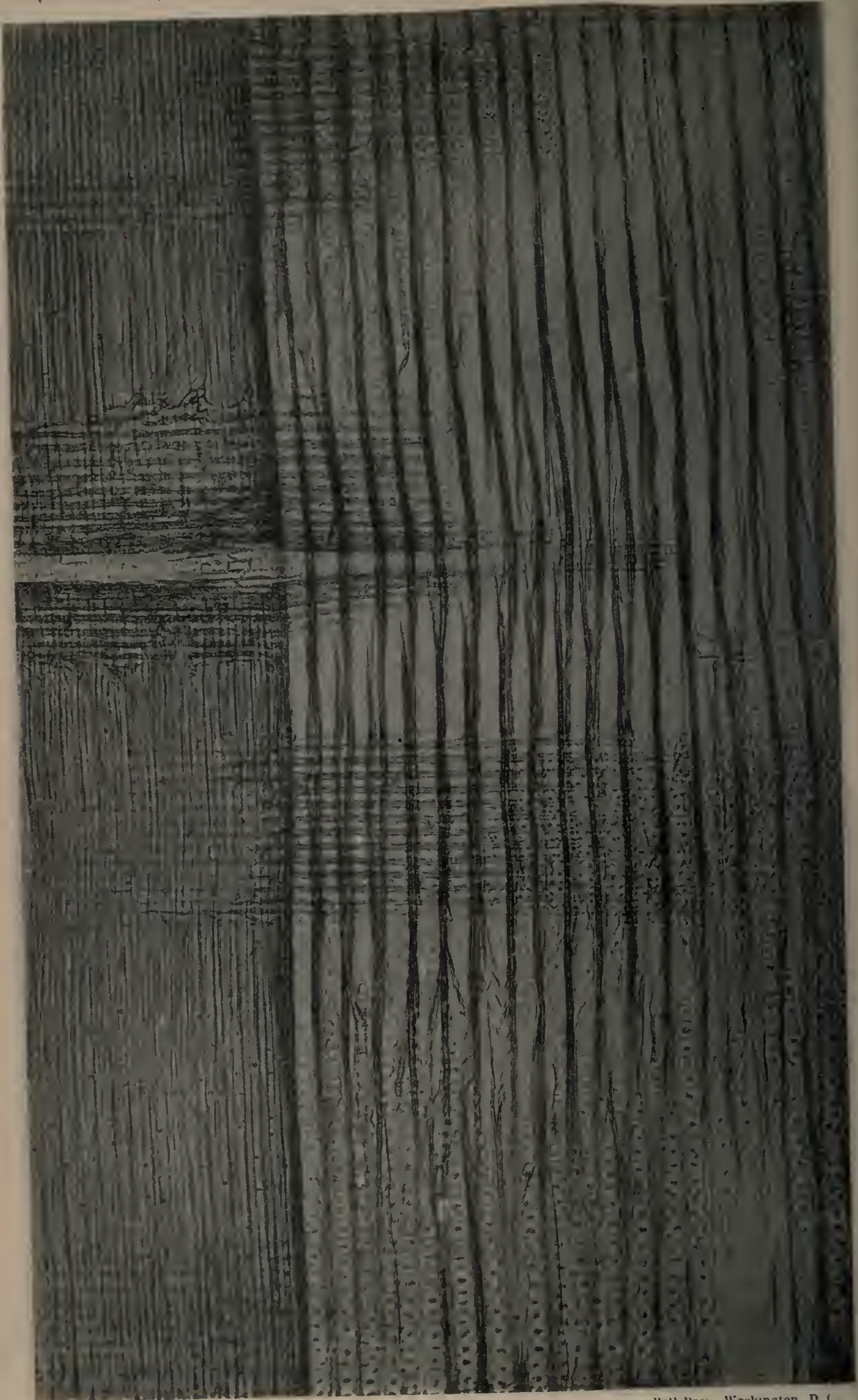


Photomicrograph by P. H. Dudley.

Bell Bros., Washington, D. C.

401. Larix Americana, Michaux; Tamarack.

Tangential Section x 100 Diameters.

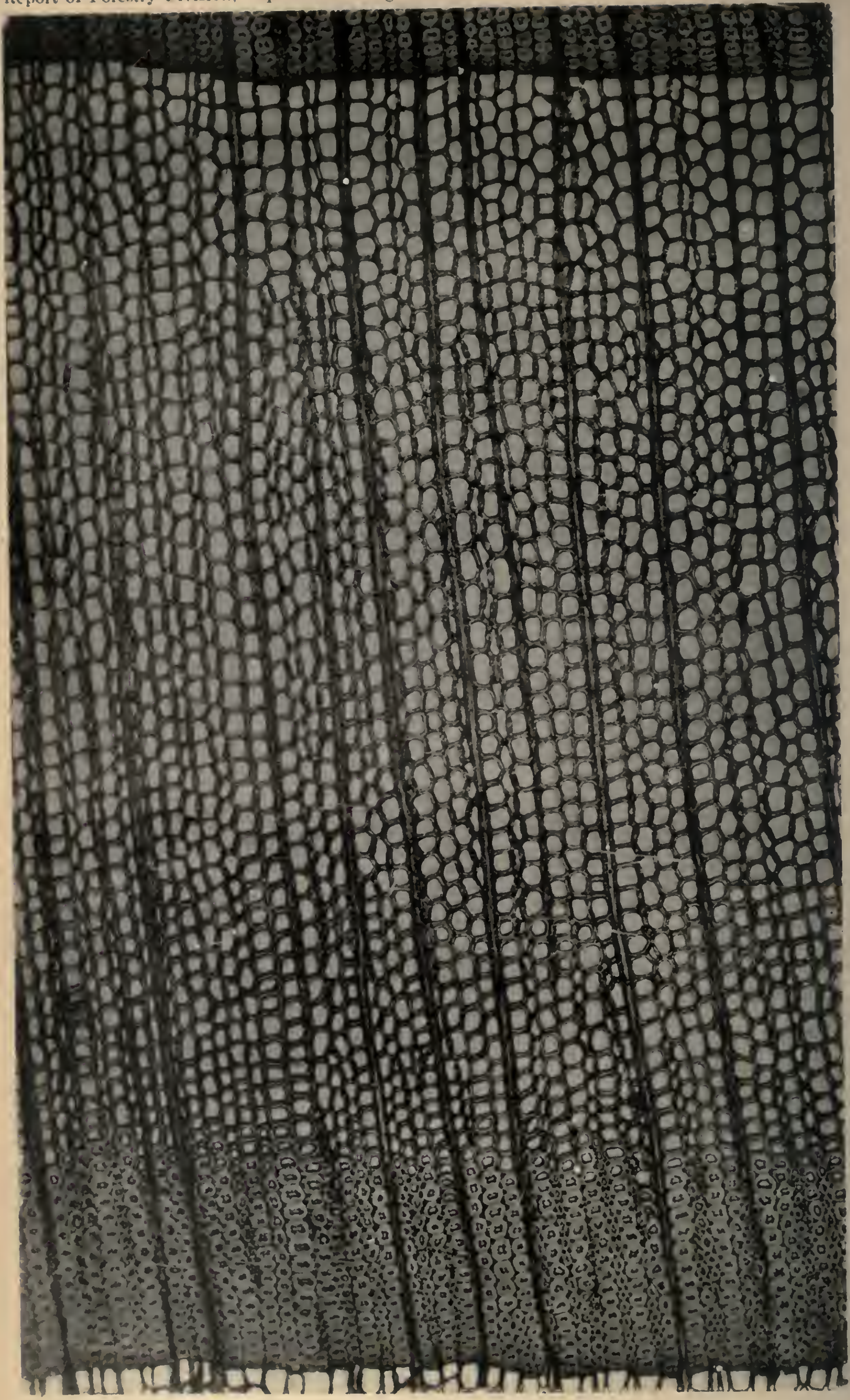


Photomicrograph by P. H. Dudley.

Bell Bros., Washington, D. C

401. Larix Americana, Michaux; Tamarack.

Radial Section x 100 Diameters.



Photomicrograph by P. H. Dudley.

Bell Bros., Washington, D. C.

401. Larix Americana, Michaux; Tamarack.

TAMARACK, *Larix Americana*, Michx. No. 401.

The photomicrograph of the transverse section shows a zone of hard, dense, nearly solid tracheids, which form from one-sixth to one-third of the annual ring, and, like those of *Pinus palustris*, have a sharp line of demarcation where the two classes join in the ring. These two species of trees attain their greatest development in opposite portions of the country: the Tamarack in the North, and the Yellow Pine in the South. The resin-canals in the former are confined to the zone of thick-walled tracheids, and are usually near the outer portion of the ring. The cells which form the exterior portion of the canal are much thicker and firmer than those in *Pinus palustris*, and the area of the canal is also much less. Generally two canals are in close proximity, but without any apparent connection.

The thin-walled tracheids in different trees vary somewhat in size, ranging from 0.0025 of an inch to 0.002 of an inch in diameter in a radial direction, and from 0.002 to 0.0015 of an inch in a longitudinal direction. The lumen measures from 0.001 of an inch to 0.0013 of an inch, the walls being much thicker than those of some other woods, a feature which gives this wood greater wearing qualities.

In many parts of the transverse section the division between the lamellæ joining the cells can be seen, something that cannot be made out in any of the other Conifers. The medullary rays are quite numerous and of considerable size, showing their cavity quite clearly with this magnifying power. The lenticular markings on the cells are most abundant near the ends, and less frequent in the middle, and the swelling of many of the walls parallel to the medullary rays is due to the cross-section of such markings. This peculiarity of the markings is also seen in the radial section.

In the radial section the lines crossing the page represent the medullary rays, the walls of which are very thick and strong, the thin places in them being very small. In the central ray is seen a longitudinal section of one of the resin-canals of the medullary system. In the tangential section the medullary rays are seen to be cells arranged in single rows, usually from six to eighteen cells superimposed one above the other, except in those rays inclosing a resin-canal. The thickness of the walls is very apparent, and of great importance in preventing decay.

The quality of the wood of this tree is such that it deserves to be more widely known and more extensively used for ties than it has been; yet where its growth is abundant adjacent to their lines, a few railroad companies have employed it for ties. But it was only in a few localities, where the timber was thus situated, that these ties were found recently put in. Each annual ring has a zone of hard, dense tracheids, which render it capable of sustaining the heaviest freight traffic; its durability, too, is another feature of great importance.

Preservation and Fungi.—This wood is easily treated with antiseptics to prevent decay, especially with sulphate or acetate of iron; and ties so treated have lasted over thirty years under heavy traffic. These ties were originally 9 feet long, having been moved under the rails three times, and were destroyed only by continued spiking. The sap-wood did not show evidence of decay exceeding one-eighth of an inch in depth; while the wood within was sound and bright. Untreated Tamarack ties last from five to eight years.

The decay was not uniform; in most cases it was from the outside inward, the sap-wood being destroyed first; in others the decay was from the bottom upward. Unfortunately, however, these observations are somewhat incomplete, as the history of the ties could not be satisfactorily traced.

The fungi which grow on this wood are *Polyporus pinicola*, Fr., and *Polyporus abietinus*, Fr.

Western Larch, *Larix occidentalis*, Nuttall. No. 402.

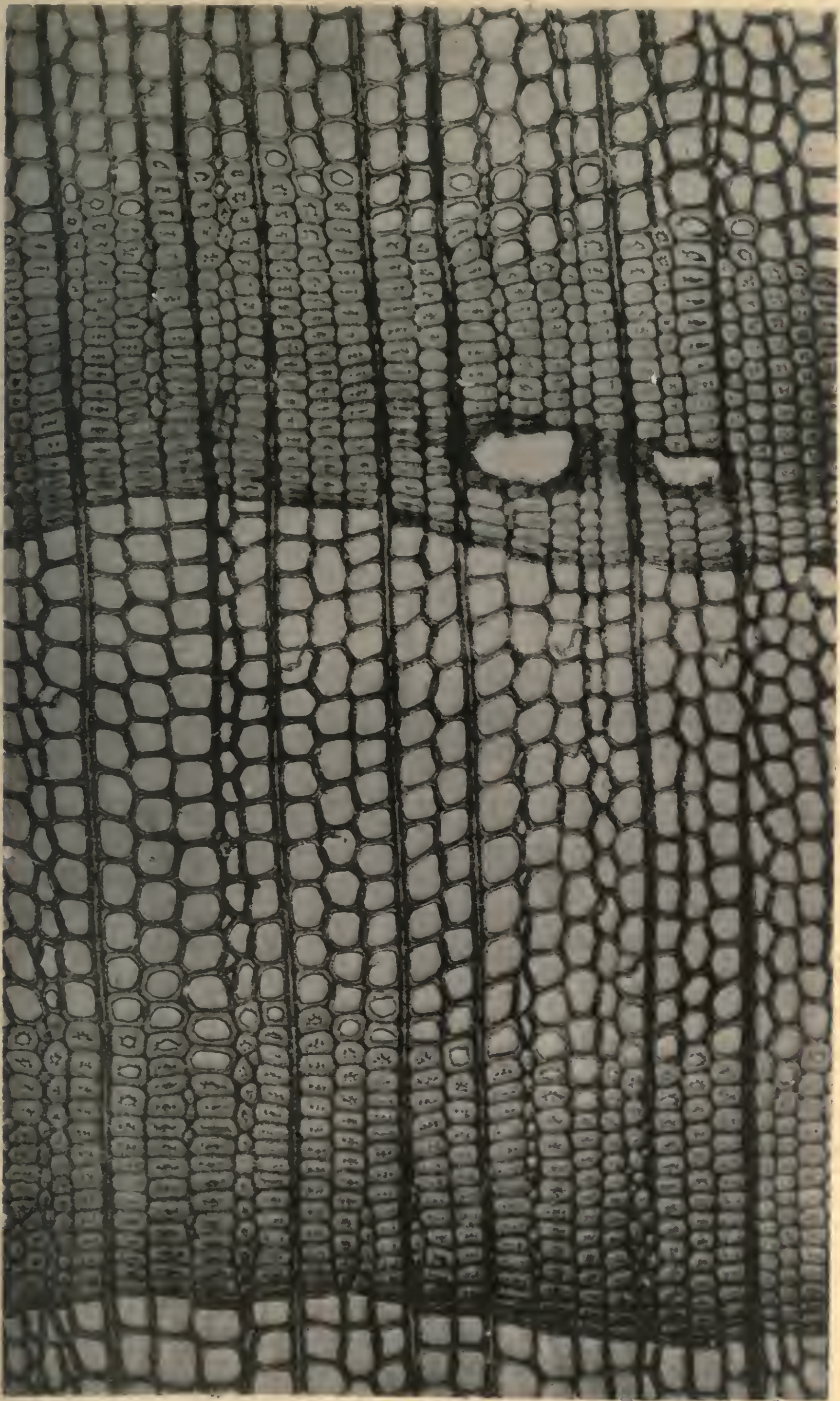
The photomicrograph of the transverse section shows this to be a much harder and more dense wood than that of the preceding species; the thin tracheids are larger and nearly rectangular, the largest of them measuring .0025 of an inch, with a lumen .002 x .002 of an inch, the walls of which are comparatively thick.

The decidedly tabular thick-walled tracheids measure .002 x .0013 of an inch, the lumen being very small, in many cases only a trace of a cavity; and, comparatively speaking, the thick-walled cells comprise a greater number of rows than the thin-walled ones, a feature which gives to this wood increased hardness, strength, and elasticity over the preceding species. The line of demarcation between the two classes of tracheids in the same layer is distinct and sharp.

The number and form of the resin-canals is quite similar to those of the common Tamarack. In the radial section the lenticular markings are not so frequent; generally but one row is found on the side of the thin-walled tracheids, where, in the preceding species, there are commonly two rows. The medullary rays are in broad bands, with a structure almost identical with that of the Tamarack. In the tangential section the medullary rays are in single rows, except when inclosing a resin-canal; but the cells are larger and more conspicuous than in the preceding species.

Table I.—*Comparative average number of fibers in a square of wood $\frac{1}{100}$ of an inch on a side, or $\frac{1}{10000}$ of the area of a square inch.*

No.	Woods.	Remarks.
251	White Oak	268 small fibers in the dense masses.
290	Chestnut	150 " " " " " Great variation in different specimens of this wood.
329	White Cedar	110 thick tracheids; 70 thin tracheids.
380	Yellow Pine	60 thick tracheids; 30 thin tracheids.
387	Hemlock	86 thick tracheids; 38 thin tracheids.
401	Tamarack	116 thick tracheids; 33 thin tracheids.
402	Western Larch	54 thick tracheids; 24 thin tracheids.



Photomicrograph by P. H. Dudley

Bell Bros., Washington, D. C.

402. Larix Occidentalis; Western Larch.

Transverse Section x 100 Diameters.

The above figures would vary, to some extent, for different specimens, but they give an approximate idea of the minuteness of the cellular structure, and are thus very instructive.

TABLE II.—*Specific Gravity.* *

No.	Woods.	Minimum.	Maximum.	Average.	Weight per cubic foot.
251	White Oak	0.6006	0.8670	0.7470	46.35
290	Chestnut	0.3829	0.4720	0.4504	28.07
329	White Cedar	0.2900	0.4527	0.3322	20.70
380	Yellow Pine	0.5191	0.9325	0.6999	43.62
387	Hemlock	0.3343	0.5191	0.4239	26.42
401	Tamarack	0.5389	0.7779	0.6236	38.86
402	Western Larch	0.5897	0.8340	0.7407	46.16

TABLE III.—*Chemical Analysis.*

No.	Woods.	Hydrogen.	Carbon.	Oxygen.	Ash.	Specific gravity.
251	White Oak	6.59	50.44	42.73	0.24	0.7635
290	Chestnut	5.75	48.73	44.69	0.83	0.7143
380	Yellow Pine	7.41	58.61	33.72	0.26	0.7414
380	Yellow Pine	7.26	56.19	36.30	0.15	0.8469
380	Yellow Pine	6.70	52.70	40.32	0.28	0.6236
380	Yellow Pine	6.85	52.99	39.88	0.28	0.8988
380	Yellow Pine	6.83	54.78	38.15	0.24	0.8983
380	Yellow Pine, thick tracheids	6.22	49.13	44.65	....	....
380	Yellow Pine, thin tracheids	6.13	49.81	44.06	....	....
387	Hemlock	5.91	52.38	41.23	0.48	0.4097
401	Tamarack	6.03	51.91	41.79	0.24	0.7024

For the analysis of the thin- and thick-walled tracheids the wood was well air-seasoned; they were then separated, each class weighed, and dried at 100° C. The loss of water and volatile hydrocarbons for the thick-walled tracheids was 10.48 per cent., and for the thin-walled, 11.38 per cent. Both were next treated with ether to extract the resinous matter, the thick-walled cells yielding 19.59 per cent., and the thin ones, 20.97 per cent. The tracheids were then burned in oxygen, giving the respective results as previously stated. Contrary to what was hoped, the percentages do not explain or throw much light on the difference in physical properties of the two classes of tracheids.

TABLE IV.—*Longitudinal crushing Strength in Relation to Specific Gravity.*

No.	Woods.	Average of specimens.	Crushing strength per square inch.	Specific gravity.	Ratio.
251	White Oak	8	7,458	0.7516	9,923
290	Chestnut	4	5,804	0.4439	13,075
329	White Cedar	3	3,697	0.3429	10,781
380	Yellow Pine	5	9,081	0.7228	12,564
387	Hemlock	6	5,549	0.4246	13,086
401	Tamarack	4	8,297	0.6197	13,888
402	Western Larch	5	9,991	0.6420	15,560

* From Tenth Census Report, Vol. IX., 1880.

Tests upon the crushing strength (tensile and transverse) of different specimens of the same species of wood show that there is a quite constant ratio between each and the specific gravity, thus agreeing with what has been stated as to the presence or absence of certain dense cells in the microscopical structure of the layers. So that one who is skilled, with the aid of a miscroscope, can make a very close estimate of the comparative suitability of different pieces of wood for definite purposes. As a case in point, a railroad company, doing a heavy freight business, being able to buy cedar ties for one-third the cost of oak, for this reason put them down, but only to find that after they had injured one set of rails these ties were too soft for their heavy traffic. A microscopical examination of the timber would have enabled one to predict what the result would be and to save the expensive trial.

Table IV. shows the ratios between the longitudinal crushing strength and the specific gravity of the woods under consideration. The ratios are obtained by dividing the crushing weight per square inch by the specific gravity, which gives a ratio representing the crushing weight of a square inch having a specific gravity of one. The average for White Oak, as given in the table, is 9,923 pounds, which for practical purposes might be called 10,000 pounds. If we compare oak grown south of the fortieth parallel, the result will be 10 per cent. higher.

Having another piece of oak, the specific gravity of which is 0.6578, and wishing to know its approximate crushing weight, we obtain it by multiplying its specific gravity by 10,000, which gives 6,578 pounds. The same method applies to other woods.

Comparing one wood with another, taking White Oak as unity, the comparative crushing strength of Chestnut is 1.3 per unit of specific gravity; White Cedar, 1.07; Yellow Pine, 1.25; Hemlock, 1.3; Western Larch, 1.55; Tamarack, 1.38. The crushing strength given in the table is for blocks eight diameters in length. For larger ones the strength would be less. In using them a factor of safety must be adopted most suitable for the work. The table gives data which, to a great extent, can be used to determine the proper size of columns of one wood to be substituted for another, by giving the proper dimensions and retaining approximately the same factor of safety, a matter which has been neglected in too many cases.

TABLE V.—*Resistance to Indentation.**

[Pressure in pounds per square inch for indentations of one twenty-fifth of inch.]

No.	Woods.	Pressure.
251	White Oak	2,974
290	Chestnut	1,446
329	White Cedar	878
380	Yellow Pine	2,637
387	Hemlock	1,359
401	Tamarack	1,265
402	Western Larch	2,271

*From the Tenth Census Report, Vol. IX., 1880.

These tests were made upon small pieces of wood, about 1½ inches in width. It is difficult to combine them so as to represent the proper relations of the layers of wood in a tie. These tests were also made upon dry wood. Made upon actual ties, containing the same percentage of moisture as those in the ballast, the results would be modified; Chestnut would not show so high, and Cedar would be reduced but little; Hemlock would be lower, as also the Yellow Pine; and after three years' decay the results would be still further modified. The Hemlock would show marked depreciation, also the Yellow Pine; the Cedar would be quite uniform, while the Oak and Chestnut would show some reduction.

Experience shows that, with the exception of White Cedar, if the fibers can be protected from becoming softened, they are sufficiently hard to sustain from twice to three times as much traffic as they do when untreated.

Length and size of ties.—For a 4-foot 8½-inch guage the majority of railroads use a tie 8 feet long; some 8½ feet long, and a few 9 feet.

Specifications call for a 6-, 7-, and 8-inch face for the flatted ties; and some roads call for joint-ties with a 10-inch face. In depth the dimensions vary from 6 to 7 inches. The Chestnut ties now being bought are required to be 7 inches deep. A few roads use Cedar ties only 6 inches deep, but most of the recent ones are 7 inches. With Chestnut and Cedar ties this is perhaps advisable, but with other woods, owing to the manner of decay, it is doubtful whether anything is gained.

Most of the Yellow Pine ties which reach the North are rectangular and uniform in size. The New York Central and Hudson River Railroad Company use a tie 9½ by 6½ inches and 8 feet long; sixteen of these are put under a 30-foot rail, making the space between each one narrow for tamping such deep ties, and requiring more time and care to do the work. But of course the track remains very firm after it is put up.

RECAPITULATION.

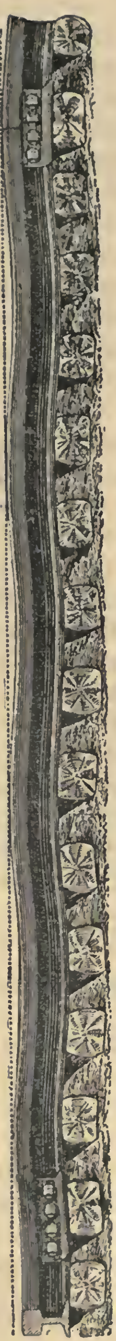
Destruction of ties.—Railroad ties in service are injured, destroyed, and rendered unserviceable by three principal causes:

(1) Mechanical disintegration of the layers, and the abrasion of the fibers under the rails.

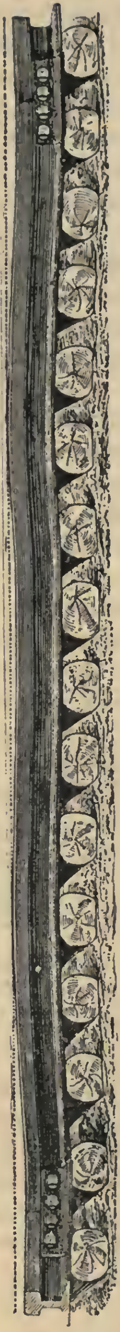
(2) Injury to the wood by spiking and respiking.

(3) General decay of the wood, induced by fungi.

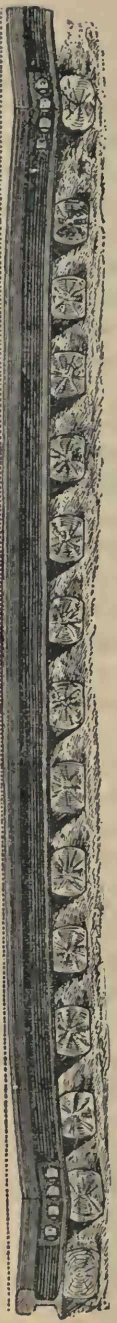
In regard to the first cause, extensive examinations show that there is more or less up-and-down movement of the rails under all passing trains. This is true to some extent of tracks laid with even the heaviest and stiffest rails that are used at the present time, but the undulation of such tracks is greatly reduced.



No. 1. Represents the long waves which are found to take place, more or less, in the best surfaced tracks under the weight of the cars; the deflections are only from $\frac{1}{8}$ to $\frac{3}{16}$ of an inch, the rails returning quite to surface upon passage of the cars.



No. 2. Represents the first form of permanent set in rails, low at the joints and center and high at the quarters.



No. 3. Represents the second form of permanent set in rails, low at the joints and high in the center.

Figure 1 is intended to represent the general appearance of the undulations in the surface of the rails as they take place under the wheels of passing trains. The lighter the rail and lower the standard of track maintained, the greater these undulations become. After they have taken place, and have been allowed to continue, the rails soon acquire a permanent set, and are found to be like those represented in No. 2. If the labor is inadequate to maintain the track under the service, the rails soon take the form shown in No. 3, which will be recognized as being a common type of a permanent set in rails, though rapidly disappearing in the best maintained tracks.

In both the latter forms the rails will be found loose on the ties under the spikes, and are pressed down by every pair of wheels that passes them. The ties not only have to sustain the load upon the wheels, but also to receive the dynamic shock of the falling rail and load; and, as a consequence, there is a very rapid abrasion of the ties and a chafing-out of the throat of the spikes. The softer the wood the faster will be the cutting.

The inspection of thousands of miles of railroad track each year has given me excellent opportunities of studying this phase of tie-destruction. The sections of many of the steel rails which are in the tracks are too light for the present traffic, and must soon be worn out, and the ties are cut down with great rapidity. The section of our rails are being made heavier, but not as much with reference to stiffness as is desirable. So far as I know, the stiffest section in proportion to the weight of any rail yet used, is the 80-pound section, designed and now used by the New York Central and Hudson River Railroad Company, and under heavy traffic it shows a decided advantage over the lighter and weaker sections.

It will be unnecessary to remark upon the other two statements, as they have already been sufficiently considered.

ADHESION OF SPIKES IN TIES OF VARIOUS WOODS.

In the following experiments the White Oak and Chestnut ties used were taken from the Boston and Albany Railroad track, near Allston, Mass. The Cedar tie was green, having been cut in the spring, and the tests were made on it in August. It had not been in service, nor had the Yellow Pine or Hemlock. The Oak tie and one of the Chestnut ties had been in the track only two years and three months, and they were of good sound second-growth timber. The other Chestnut tie had been in service four years and three months. The results obtained from these experiments are of far more practical value than if from new ties.

Maj. F. H. Parker, commanding officer of the Watertown Arsenal, kindly allowed the testing-machine to be used to make the tests, which were conducted by Mr. James Howard, C. E., in charge of the machine, a fact of itself guaranteeing the care used in making the experiments. The Boston and Albany Railroad Company sent Mr. John Twigg, an experienced spiker, to drive the spikes in the ties, the conditions of every-day practice being maintained as nearly as possible. When the ties were taken out of the track a spike was left in each end, as originally driven, and great care was taken not to disturb them in removing the ties from the track. This gave an opportunity of seeing whether the adhesion increased or decreased by age of service.

After the spikes were drawn the ties were cut into blocks and split, exposing the spike so as to show the injury to the wood-fibers, which is very marked in all cases. A blunt or poorly-pointed spike driven into the White Cedar broke the wood down in masses, so as to reduce the adhesion of the spike from 40 to 50 per cent. from that obtained with a sharp-pointed spike; the latter did not break down but cut through the fibers. In most woods driving the spike checks the fibers for some distance on either side of the spike. In oak the adhesion was increased 40 to 50 per cent. by boring a ½-inch hole for a $\frac{9}{16}$-inch square spike. The experiments show conclusively that the same kind of spike is not the most suitable for all woods.

TABLE VI.—*Adhesion of Spikes in Ties.*

[Chestnut tie in service two years and three months under 72-pound rail 4½ inches high.]

Number of test.	Length of spike.	Length driven into tie.	Tension in pounds on spike.								Remarks.
			Pounds to start spike.	At ¼ inch.	At ½ inch.	At 1 inch.	At 1½ inches.	At 2 inches.	At 2½ inches.	At 3 inches.	
1	5.50	4.50	1,496	1,185	954	630	......	......	......	......	Spike drawn in track and redriven in same hole.
2	5.50	4.80	3,166	2,716	2,305	1,814	1,072	......	......	......	Spike as driven by railroad company when tie was put in track.
3	5.25	4.40	3,118	2,200	2,000	1,720	......	......	......	......	New Boston and Albany Railroad spike, good point, driven into solid wood.
4	5.50	4.60	3,572	2,305	2,036	1,560	......	......	......	......	New New York Central and Hudson River Railroad spike driven into solid wood.
5	5.50	5.00	2,886	2,960	2,548	1,100	......	......	......	......	Spike as driven by railroad company, corroded and bent; broke out piece of wood in drawing.
6	5.50	4.60	1,700	1,924	1,550	1,140	......	......	......	......	Old spike redriven in old hole.

[Chestnut tie in service four years and three months; cut under rail.]

7	5.50	4.40	2,794	1,700	¾ in. 1,430	1,280	......	......	......	......	Spike as driven by railroad company; wood under rail brittle and soft four to five layers down.
8	5.50	4.40	2,265	1,706	1,240	950	......	......	......	......	Spike driven into wood under rail two hours before test; fermentation commenced under fourth layer of wood.
9	5.70	4.80	3,200	2,548	2,390	2,150	......	......	......	......	Spike driven into sound wood.
10	5.30	4.60	2,280	1,030	1,020	880	......	......	......	......	Spike as driven by railroad company; corroded, scales separate, and remain in wood.

TABLE VI.—*Adhesion of Spikes in Ties*—Continued.

[Yellow Pine, 4 by 8 inches; cut in winter of 1886.]

Number of test.	Length of spike.	Length driven into tie.	Tension in pounds on spike.								Remarks.
			Pounds to start spike.	At ¼ inch.	At ½ inch.	At 1 inch.	At 1½ inches.	At 2 inches.	At 2½ inches.	At 3 inches.	
11	5.50	4.80	3,290	1,390	1,210	1,014	740	......	......	......	New York Central and Hudson River Railroad spike driven tangentially to layers; after yielding fell to 1,500.
12	5.50	4.80	3,195	1,650	1,250	840	......	......	......	......	New York Central and Hudson River Railroad spike; pull fluctüated between 1,300 and 2,200, until spike was drawn to ¼ of an inch.
13	5.00	4.40	3,110	1,750	1,460	1,280	......	......	......	......	Boston and Albany spike.
14	5.50	4.65	2,650	1,200	1,050	995	890	820	......	......	½-inch hole bored full length of spike.
15	5.50	4.70	3,010	1,500	1,550	1,300	980	760	......	......	7/16-inch hole bored full length of spike.
16	5.50	4.70	3,250	2,400	1,900	1,400	1,020	880	......	......	⅜-inch hole bored full length of spike.
34	½-inch Lag-screw	3 in. of screw	2,850	3,510	2,590 ⅜-in., 2,960	940	......	......	......	......	Lag-screw driven in same block with spike hammer.
[Yellow Pine, 4 by 8 inches, seasoned nine years.]											
17	5.50	4.50	3,340	2,240	2,040	1,860	1,480	920	......	......	
18	5.70	5.00	3,640	2,595	2,600	2,560	1,980	1,500	920	......	At 3 inches, 310; sudden drop to 2,700.
19	5.60	4.80	3,445	2,110	2,080	1,790	1,380	940	235	......	At 3½ inches, 180.
20	5.40	3.00	1,870	1,320	1,050	560	......	......	......	......	
[White Cedar]											
22	5.50	4.90	2,305	2,190	2,010	1,640	1,240	760	390	......	Sharp-pointed spike.
23	5.50	4.70	1,460	1,170	1,080	830	......	......	......	......	½-inch hole bored full length of spike.
24	5.50	4.70	1,755	1,360	1,250	1,050	840	680	......	......	⅜-inch hole bored full length of spike.
26	5.60	5.00	1,320	1,150	1,010	680	620	530	420	......	Blunt-pointed spike had broken the wood.
21	⅝ (Lag-screw)	3.40 2.80	2,200 7/16-in. 26.10	2,080	840	480	380	290	......	......	½-inch hole bored.
25	⅝ (Lag-screw)	3.40 2.80	2,825	1,950	1,150	580	......	......	......	......	Spike was drawn 3/16 of inch at 2,700; ⅜-inch hole bored.
[White Oak, fine quality, in service two years and three months.]											
27	5.50	4.70	4,490	3,490	2,910	2,150	1,620	1,220	710	460	Spike as driven by railroad company.
28	5.50	4.60	3,360	2,700	2,220	1,280	670	......	....	......	Old spike redriven in old hole thirty hours before test.
29	5.60	4.70	4,330	3,260	3,010	2,880	2,250	1,830	1,420	920	New spike in solid wood.
30	5.70	4.90	6,595	5,695	5,480	4,800	4,250	3,300	2,400	1,129	½-inch hole bored full length of spike.
31	5.70	4.80	3,370	2,380	2,140	......	......	...	....	....	Old spike redriven thirty-one hours before test.
32	6.00	5.30	3,965	3,180	2,900	2,150	......	......	......	......	Spike as driven by railroad company.
33	5.60	5.00	5,970	⅜-in., 4,800	4,580	3,900	3,390	2,480	1,820	830	Suddenly drew to ¼-inch at first load; experiment repeated to confirm experiment 30.

TABLE VI.—*Adhesion of Spikes in Ties*—Continued.

[Dry Hemlock tie, cut in winter of 1886; spikes driven seventy-five days previous to tests.]

Number of test.	Length of spike.	Length driven into tie.	Tension in pounds on spike.								Remarks.
			Pounds to start spike.	At ¼ inch.	At ½ inch.	At 1 inch.	At 1½ inches.	At 2 inches.	At 2½ inches.	At 3 inches.	
35	5.50	4.90	3,110	$\frac{5}{16}$ 2,000	2,100	1,800	1,750	1,300	2½ in. 950	3 in. 540	Spike driven in ⅜-inch hole; yields suddenly and stops.
36	5.50	4.75	3,390	2,060	1,900	1,700	1,280	1,060	880	420	Spike driven in ½-inch hole; yields suddenly and stops.
37	5.00	4.25	3,690	1,800	1,650	1,080	820	420	......	......	Spike driven into solid wood.
38	5.50	4.55	3,280	1,850	1,600	1,050	880	810	......	......	Spike driven into solid wood; yields suddenly at start.
39	⅝-in. Lag-screw	3.20	3,580	2,580	1,900	910	520	280	......	......	⅜-inch hole bored; size of screw, ½-inch; fibers of wood are sheared off.
40	⅝-in. Lag-screw	3.25	4,290	3,600	1,280	900	510	380	......	......	½-inch hole bored; size of screw, ½-inch; fibers of wood are sheared off.

The table giving the adhesion of spikes shows some important features, a part of which will be new to the general railway public.

In Chestnut of second-growth the tension necessary to start an ordinary $\frac{9}{16}$-inch square spike, 5½ inches long, and driven home upon a rail, ranges from 3,000 to 3,600 pounds. After being drawn one-half an inch, the adhesion is diminished to only about two-thirds of these amounts, and at 1 inch is reduced to about one-half. This is of great importance when blocking up the track in winter, as a spike slightly redrawn will still hold.

A spike redriven in an old hole holds about 50 per cent. of the amount that it will when first driven, unless the ties have been in service over three years. In the test of the second Chestnut tie it will be noticed that the adhesion of the spike has decreased with the length of the service.

Experiment No. 8 shows that the adhesion of a spike driven into wood under the rails, after fermentation had taken place, is much decreased, as might be expected.*

In Yellow Pine the resinous matter forced out of the fibers by the compression produced in driving the spike lubricates the latter so that the adhesion is not as great as it should be according to the specific gravity of the wood; and after the spike is started the adhesion decreases rapidly. This feature has been noticed when the rails are raised up on thick shims, the spikes holding but little in the ties, and being easily displaced.

The fibers of the wood are broken and bent down, so that they do not close up tightly to the body of the spike, as in Chestnut and Oak ties.

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* See Figs. 1 and 2, p. 61.

Experiments 14, 15, and 16 show the results of boring holes for the spikes. The $\frac{1}{2}$-inch hole seemed too large; the $\frac{7}{16}$-inch hole showed an improvement; while the $\frac{3}{8}$-inch one gave the best results.

Experiments 17 to 19, inclusive, are instructive, and correspond to spikes driven into dry bridge ties; showing also the increased adhesion gained by driving spikes tangentially to the layers of wood; of course, ties ballasted would not be as dry as this timber.

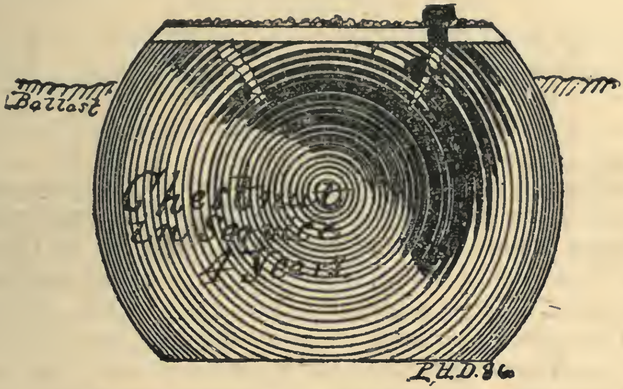

Fig. 1. Cross-section of a tie showing the effect of spiking.

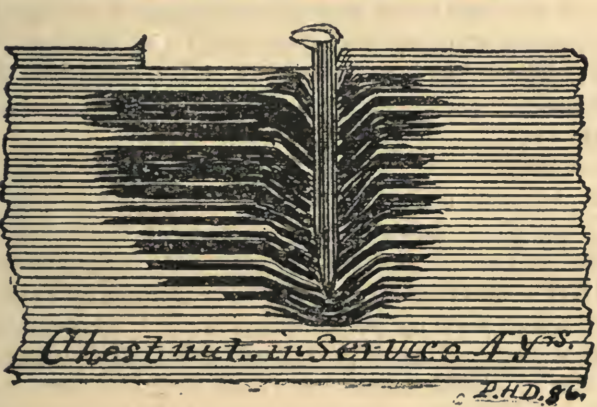

Fig. 2. Longitudinal section of a portion of a tie showing the effect of driving a spike.

White Cedar gives the most irregular results. No. 22 is good, and probably above the average results; No. 26 was in the same tie, but the spike was blunt and tore the wood, leaving but little in front and back of the spike; such results are common in practice. Nos. 23 and 24 show the improvement over No. 26 gained by boring holes; the adhesion was increased as the spike was drawn out at different lengths.

The White Oak tie holds a spike firmly, not giving up its hold rapidly as it is drawn out. Boring holes increases the adhesion* and materially lessens the checking of the layers and injury to the wood-fibers.

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* See experiments No. 30 and 33, p. 59.

In the tests of the Hemlock tie the spikes were driven tangentially to the layers of wood, and at the start the adhesion ranged from 3,280 to 3,690 pounds, but when drawn one-fourth of an inch decreased nearly one-half. The fibers were too much injured to cover and press the spike firmly. Boring holes increased the resistance, as shown when the spike was drawn out to various lengths, the fibers not being injured so much.

NOTE ON ADHESION OF SPIKES.

By B. E. Fernow.

More extensive experiments on the adhesion of spikes were recently published in the "Organ für das gesammte Eisenbahnwesen." The writer comes to the conclusion that by boring holes for the spikes not only is there effected a saving of probably 50 per cent. in spikes, but also a large saving in ties, especially in oak ties, in which, by driving the spikes, the tendency to check is aggravated more than in pine. As set forth in the above report, spiking breaks down the fibers around the spikes, thus inducing earlier decay and at the very places where most resistance is required; and frequent respiking wears out the tie mechanically sooner than in any other way; the bending, too, of the spikes when driven, increases these evils. Unless such mechanical wear is counteracted, it becomes doubtful whether impregnating ties can be considered the right economy.

In these experiments 170 ties, laid down as they came, were bored on one rail-side, and not on the other; the driving of spikes was then done as in practice. After having started the spike (with a regular spike-puller) to 1 inch, a grapple connected with a balance was attached to the rail and weights added to the balance until the rails suddenly gave way; the grapple drawing perpendicularly, and all other forces being ingeniously counterbalanced, the adhesion alone was determined.

Boring-bits of different sizes were used, and the holes were made 4 and 5 inches deep. The conclusions arrived at are recorded as follows:

(1) Adhesion differs greatly in ties of the same kind, as well as in the same tie.

(2) Even the four spikes in each tie show considerable difference of adhesion.

(3) Adhesion is sometimes greater with the inner, sometimes with the outer spikes; sometimes when holes are bored, sometimes when not; sometimes in holes of a larger, sometimes in those of a smaller diameter.

From all of which it appears that generalization on a small number of experiments can be done only with caution. Not only the boring, but also the quality and kind of tie, the seasoning, the temperature and weather in general, the places into which the spikes are driven, whether driven more into the heart-wood or into the sap-wood; the closeness, too, of the contact with the foot of the rail requires consideration in determining the adhesion of the spike for practical purposes. Yet, from the average results represented in the seven tables, the following important conclusions can be drawn:

A. For Oak.

(1) In ties with good, tough, dense fibers the adhesion was found to be greater when holes of $\frac{7}{16}$ or even $\frac{1}{2}$ an inch were bored than when this was not done.

(2) In quickly-grown oak ties the reverse was the case, but the difference was insignificant (−67.2); and as such ties split and check more easily, boring of these also must be considered advantageous.

(3) The friction due to presence of water in the tie (influence of the weather) exerts greater resistance to displacement than the friction of the spikes against the rails.

(4) In a $\frac{3}{8}$-inch hole the average adhesion was slightly less than when the ties were not bored (—24).

(5) Only in holes of small diameter was the average adhesion less than when not bored, while with an increase of the diameter of the hole the adhesion increased (−136 : +112.8 : +144).

(6) The most favorable results were given by a $\frac{7}{16}$-inch hole (1 : 35.4). The largest-sized hole gave not much less favorable results (1 : 31.8).

(7) If the common four-cornered wedge-pointed spike is to be used in unimpregnated oak ties, it is best to use a boring-bit of the same size as the spike.

(8) The results of experiments with 200 spikes on 50 ties would allow the conclusion that new oak ties, unimpregnated, and with square, wedge-pointed spikes, show the same average adhesion whether bored or not; though the boring is recommended, nevertheless, for other advantages.

These results would probably have a like bearing for impregnated ties.

B. For Pine.

(Probably for other coniferous woods and Chestnut.)

(1) By using a boring-bit from $\frac{5}{16}$ inch in size upward, the adhesion was increased; the best results were given by a $\frac{3}{8}$-inch hole (1 : 13.5); and a $\frac{7}{16}$-inch hole was not much less favorable (1 : 10.5).

(2) When the hole was increased to 5 inches in depth there was a decrease of adhesion, though only insignificant.

(3) In pine ties the *place* where the spike is driven is of greater importance than in hard-wood ties, the adhesion diminishing according as the spike has more hold in the sap-wood than in the heart-wood.

(4) Experiments with 400 spikes on 90 ties allow the conclusion that boring increases the adhesion, especially when the bit used is of the same size as the spike.

The following is a résumé of the tables, giving the results of experiments:

TABLE I.—*Hungarian Oak; dry when the spikes were drawn.*

Bore, 7/16 inch diameter; pounds to draw spike	3,624.0
No hole bored; pounds to draw spike	3,691.2
Average	3,657.6
Difference, —66.8; diff. : aver. :: 1 : 54.4.	

TABLE II.—*Same Oak; wet when spikes were drawn.*

Bore, 3/8 inch diameter; pounds to draw spike	4,399.2
No hole bored; pounds to draw spike	4,423.2
Average	4,411.2
Difference, —24.0; diff. : aver. :: 1 : 183.8.	

TABLE III.—*Silesian Oak; wet when spikes were drawn.*

Bore, 3/8 inch diameter; pounds to draw spike	4,104.0
No hole bored; pounds to draw spike	4,240.8
Average	4,172.4
Difference, —136.8; diff. : aver. :: 1 : 30.5.	
Bore, 7/16 inch diameter; pounds to draw spike	4,044.0
No hole bored; pounds to draw spike	3,931.2
Average	3,987.6
Difference, +112.8; diff. : aver. :: 1 : 35.4.	
Bore, 1/2 inch diameter; pounds to draw spike	4,648.8
No hole bored; pounds to draw spike	4,504.8
Average	4,576.8
Difference, +144; diff. : aver. :: 1 : 31.8.	

TABLE IV.—*Pine; impregnated; dry.*

Bore, 5/16 inch diameter; pounds to draw spike	1,876.8
No hole bored; pounds to draw spike	2,197.2
Average	2,028.0
Difference, —302.4; diff. : aver. :: 1 : 6.7.	
Bore, 3/8 inch diameter; pounds to draw spike	1,843.2
No hole bored; pounds to draw spike	1,711.2
Average	1,777.2
Difference, +111; diff. : aver. :: 1 : 13.5.	
Bore, 7/16 inch diameter; pounds to draw spike	2,054.4
No hole bored; pounds to draw spike	1,867.2
Average	1,960.8
Difference, +187.2; diff. : aver. :: 1 : 10.5.	

TABLE V.—*Pine; not impregnated; dry.*

Bore, 5/16 inch diameter; pounds to draw spike	1,696.8
No hole bored; pounds to draw spike	1,572.0
Average	1,634.4
Difference, +124.8; diff. : aver. :: 1 : 13.7.	

Bore, ⅜ inch diameter; pounds to draw spike	1,545.6
No hole bored; pounds to draw spike	1,615.2
Average	1,580.4

Difference, —69.6; diff.: aver. :: 1 : 22.7.

Bore, $\frac{7}{16}$ inch diameter; pounds to draw spike	1,593.6
No hole bored; pounds to draw spike	1,646.4
Average	1,620.0

Difference, —52.8; diff.: aver. :: 1 : 30.7.

Bore, $\frac{7}{16}$ inch diameter (without rail); pounds to draw spike	1,737.6
No hole bored (without rail); pounds to draw spike	1,802.4
Average	1,770.0

Difference, —64.8; diff.: aver. :: 1 : 27.4.

(TABLE VI.—*Beech.*)*

TABLE VII.—*Pine; impregnated; wet; depth of hole bored*, 5 *inches.*

Bore, ⅜ inch diameter; pounds to draw spike	1,715.7
No hole bored; pounds to draw spike	2,028.6
Average	1,872.2

Difference, -312.9; diff.: aver. :: 1 : 5.98.

(Not bored and without rail; pounds to draw spike	1,772.4)
Bore $\frac{7}{16}$ inch diameter; pounds to draw spike	1,673.7
No hole bored; pounds to draw spike	1,911.0
Average	1,792.4

Difference, —237.3; diff.: aver. :: 1 : 76.

(Not bored and without rails; pounds to draw spike	1,629.6)
Bore, ½ inch diameter; pounds to draw spike	1,785.0
No hole bored; pounds to draw spike	1,824.9
Average	1,805.0

Difference, —39.9; diff.: aver. :: 1 : 45.2.

(Not bored and without rail; pounds to draw spike	2,053.8)

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*The results obtained from experiments with beech ties were unsatisfactory and not of sufficient value to be introduced.

Appendix 2.

WOOD PRESERVATION.*

By Henry Flad, C. E., *Saint Louis, Mo.*

Wood is made up of small fibers, the various forms of which constitute its cell-structure. Air occupies the cells not filled with sap.

The woody fiber in all kinds of wood is composed of the same elements, and in nearly the same proportions. It consists of 52.4 parts of carbon, 5.7 parts of hydrogen, and 41.9 parts of oxygen.

Differences in the strength of timber are due to differences in structure, or in the form and disposition of the fibers. The specific gravity of the fiber is about 1.5.

The sap consists mainly of water, and of the so-called extractive substances, such as vegetable glue, gum, gallic acid, coloring matter, sugar, albumen, etc. Besides these substances, which are found in greater or smaller quantities in almost every kind of sap, that of some kinds of wood contains special ingredients; oak contains tannin, the coniferous woods contain resin, essential oils, etc.

The quantity of sap contained in wood varies considerably in different kinds and at different seasons of the year. Freshly cut wood contains from 18 per cent. of sap (in Hornbeam) to 52 per cent. (in Black Poplar). The variation of sap at different seasons is illustrated by the observation that ash, cut in January, was found to contain 29 per cent. of sap, and 39 per cent. when cut in April.

When wood is thoroughly air-dried it still contains from 16 to 20 per cent. of water, and when air-dried wood is exposed for a time to a temperature of 277° F., the quantity of water is reduced to $\frac{1}{4}$ or $\frac{1}{5}$ of what was left in the air-dried wood.

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* In this paper notes signed with the initials H. C. are to be credited to Mr. Howard Constable, C. E., of New York city, who had kindly prepared a separate paper on the same subject, but to avoid unnecessary repetitions, his paper has been divided and used as foot-notes along with this Report.

NOTE.—The following table exhibits the weight of 1 cubic foot each of different kinds of air-dried wood and the space in a cubic foot, or 1,728 cubic inches, of air-dried wood occupied respectively by fiber, sap, and air, assuming the specific gravity of fiber at 1.5.

	Weights of 1 cubic foot.				Space occupied by fiber, sap, and air.		
	Pounds.	Per cent. of water.	Weight of water.	Weight of fiber.	Fiber. Cub. in.	Sap. Cub. in.	Air. Cub. in.
White Oak	53.3	16	8.5	44.8	830	161	662
Yellow Pine	34.4	17	5.8	28.6	530	161	1,037
White Pine	26.1	17	4.4	21.6	400	125	1,203
White Beech	45.2	18.5	8.4	36.8	681	233	814
White Elm	36.2	18.5	6.7	29.5	546	186	996
Sweet Gum	39.6	19	7.6	32.0	592	211	925
Yellow Poplar	33.0	19.5	6.4	26.6	493	177	1,058
Sycamore	33.4	20	6.7	26.7	494	186	1,054

The weight of water per cubic foot, as given in the third column of the above table, and the weight of fiber per cubic foot of lumber in the fourth column, were calculated from the observed percentage of water contained in the wood, as given in the second column.

In air-dried wood from one-third to nearly two-thirds of the volume is occupied by air, which might be replaced with some liquid if the air were removed, or partly replaced if the air were compressed. [Knapp's "Technology."]

DECAY OF WOOD.

The woody fiber by itself does not seem liable to decay; but the sap contained in it under favorable conditions undergoes fermentation, and fungi attack and destroy the fiber.

Fermentation, however, cannot take place except in the presence of air, of moisture, and of a temperature above the freezing point (32°), and below 150° F. If any one of these conditions is lacking, decay is impossible.

But if wood is to be exposed to conditions favorable to decay, special precautions and means can and should be adopted to prolong its usefulness. The sap being the prime cause of decay, it is plain that timber should be cut at a season when it contains the least quantity of it and the least amount of organic matter, viz, during winter.

It is stated on good authority that wood of proper character and age, cut during January and then air-dried, resisted decay for fifteen and sixteen years; whereas timber of the same kind, cut at different age and season, lasted only four years.*

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*NOTE.—On this point, see note on page 37. Experience has shown that wood cut in August, if properly seasoned, will last as long as that cut in winter. The manner of after-treatment will decide mostly for or against the practice of summer cutting. If no precautions are taken as to proper seasoning, the winter cutting is decidedly preferable.—B. E. F.

It is also evident that the total or partial removal of the sap from wood will retard its decay. But even if all sap were removed decay would naturally set in, if the entrance into the cells of air and water containing spores is permitted, or if no means are adopted to prevent their growth when introduced.

To prevent air and water from entering the wood its cells may be filled with some substance not liable to decay. To prevent organic life from springing up in the wood cells, antiseptics are introduced into them in the form of solutions, which act as poisons on all kinds of spores and bacteria.

NOTE.—There is no doubt whatever that wood can be preserved, successfully and to commercial advantage, to a much greater extent than is generally believed.

To experts in this field little need be said; they are aware of its extent, what has been accomplished, and the possible advantages. They know that the preservation of wood has been carried on in England and in several countries of Europe for a great many years on a very extensive scale and with the most satisfactory results, several processes being in use whose efficiency has been thoroughly established. Experience in this country has not been satisfactory, owing to a want of appreciation of certain conditions, very different from those found abroad. Among these it is noticeable that we have usually green timber to treat instead of seasoned wood, and that in some localities timber is yet too plentiful, and consequently cheap, to admit a preserving process being employed to commercial advantage. In some cases again experiments have not been satisfactory, owing to the great distances to which wood had to be transported for treatment and then to be sent back.—H. C.

METHODS OF TREATMENT.

The methods which are used, either simply or in combination with each other, in the preservation of wood, are,—

(1) Steeping in water or in antiseptic solutions.

(2) Forcing a current of water or of antiseptic solution longitudinally through the ducts of the wood, either by pressure or by suction—the Boucherie process.

(3) Steaming in closed vessels.

(4) Removing air and vapors from the cells by creating a vacuum around the wood in a closed vessel, and then injecting the antiseptic solution into the wood by applying pressure to the solution.

(1) *Steeping.*—When wood is steeped in running water its sap is diluted and gradually displaced. This is the cause of the greater durability of rafted lumber as compared with that which has not been submerged in water.

But the process is necessarily slow, and if the water in which the wood is submerged contains sediment, the process is impeded.

Steeping is also used for impregnating wood with antiseptic solutions. To allow such solutions to enter the wood the latter should first be freed from water, either by air-drying or by exposing it to heated air in kilns. Steeping requires much time (from one to two or three weeks) and can never effect a thorough impregnation of the wood. The structure of wood is such that, while it offers but slight resistance to the flow of liquids through its longitudinal ducts, it is very difficult, even under great pressure, to force any liquid from the surface to its center, at right angles to the direction of the fibers. But the entrance of any preserving liquid through the ducts and other cells is resisted by the sap remaining in the wood and by the air which fills the cells not occupied by sap, so that steeping, as generally carried out, causes the antiseptics to penetrate but a short distance from the surface of the wood.

It is evident, therefore, that wood which is to be preserved by this method of impregnation should be fully framed to the exact form in which it is to be used before it is treated.

Steeping may sometimes be useful as a process preparatory to others.

(2) *The Boucherie Process.*—About 45 years ago Boucherie, a French chemist, conceived the idea of impregnating wood with a preserving fluid, by introducing it into a living tree through a groove cut around its surface near the ground, from which it was to arise, together with the sap, through the cells of the wood.

But this was soon found impracticable, and in 1841 Boucherie patented a process for preserving wood by forcing a solution of sulphate of copper through the cells of the wood under hydrostatic pressure applied at one end of freshly cut and unbarked logs, so as to remove the sap and replace it by the solution of copper. Since then impregnation with sulphate of copper has been generally known as the "Boucherie process," although this term is more properly applied to the method of impregnation invented by him, which may also be used in connection with other preservatives as well as with copper.

To secure the ready percolation of the fluid through the cells of the wood it is necessary that the sap of the wood to which the process is to be applied should possess the greatest possible degree of fluidity. This it has during the first months of the year. Timber cut during the autumn may also be used, although the sap at that season is more viscous and less readily removed. During the spring and summer the sap contains so much gummy extractive matter that it is not fit for treatment by this process. The timber is treated in the form of round logs, with the bark left on. The treatment should be applied as soon as possible after the timber has been cut. When exposed to the action of the atmosphere, even for a short time, the sap will solidify and greatly retard the process. It is customary, therefore, to cut the logs of somewhat greater length than that ultimately required, and to saw off a few inches from the ends just before subjecting the logs to the process.

Logs which are placed in clear water immediately after they are cut will remain for some time in proper condition for treatment. If the logs are intended for railroad ties they may be cut of suitable length to make either one or two ties, and the mode of introducing the solution varies accordingly. Logs cut for single length treatment are placed (with a slight inclination) in a row on skids, and fastened to the latter by clamps. Along each row of logs runs a pipe, connected with an elevated tank which contains the antiseptic solution. Around the periphery of the end of the log nearest the pipe a greased rope is then laid and pressed against it by a plank which is drawn tight against the log by clamps.

Thus a cylindrical chamber is formed into which the solution is admitted by a rubber hose connecting the pipe with the chamber. The admission of the solution may be stopped by clamping the hose. When the solution is first admitted the air contained in the chamber is allowed to escape through a small opening near the top of the chamber, and then the solution enters the open ducts in the wood, pushing the sap before it, and finally escapes at the opposite end, where the mixture of sap and solution drips into a trough placed along and under the ends of the logs.

When logs cut to double lengths are to be treated, after having been placed on the skids they are sawed very nearly but not quite through in the middle. Wedges are then used to raise them at the middle so as to open the saw-cut wide enough to admit the introduction of a greased rope, which is placed around the circumference of the cut. The wedges are then taken out to allow the cut to close up, and thus to compress the rope and to form a close chamber. The solution enters this chamber through a short tube driven into a hole which is bored slantingly a few inches from the cut, through the end of one of the logs. Rubber hose leads from the hole in the log to the pipe. The air is allowed to escape from the chamber by using a pin to make a small hole at the top of the greased rope, which is then plugged. Of course two troughs have to be placed along and under the outside ends of the logs, where the liquid leaves the logs. The troughs carry the escaping solution to a tank, where it is restored to its normal strength. But as the solution in passing through the logs is mixed with the sap it will, even if the scum is removed with ladles and the fluid filtered through woolen cloth, soon become impregnated with foreign substances to such an extent that it cannot be safely used any longer.

This may be remedied to some extent by filtration. At the foot of the trestle carrying the tanks are placed as many filtering tanks as there are tanks on the trestle. The filtering tanks are closed by covers, which can be readily raised when the filtering material is to be introduced, and then closed and firmly anchored to the tank.

The fluid delivered by the troughs is pumped into one of the upper tanks, from which it is conducted by a pipe to the bottom of a filtering tank, whence, under a head due to the elevation of the tank, it passes upward through the filtering material and through a pipe starting from the cover of the filtering tank to a pump which raises it again to a second tank on top of the trestle. There the solution is brought to the normal strength and then starts on a new round. Such filters have to be cleaned daily.

It would appear that a cheaper, if not more expeditious, method of preventing the adulteration of the solution could be found by passing only clear water through the logs at the beginning of the treatment, continuing this process until the sap has been removed, and only then introducing the antiseptic solution. The water, after passing through the logs, would be allowed of course to run to waste.

The removal of the sap might, perhaps, be expedited and made more complete by using a weak solution of borax, instead of pure water, at the beginning of the operation.

In France, where the Boucherie process was for many years used exclusively for impregnating wood with sulphate of copper, the rule was to continue the treatment until every portion of the end from which the solution escaped showed the proper reaction when tested with ferro-cyanide of potassium. It was also a rule not to stop the operation until the solution escaping from the end, when tested by chemicals, showed a strength of two-thirds of the original solution, the wood retaining almost all the sulphate of copper at the beginning of the treatment, and gradually less, so that the solution flowing from it showed a corresponding increase in strength. The time required for thoroughly impregnating wood by this process was found to vary with the state of the atmosphere, with the dimensions of the log, and with the quality of the timber. A humid and mild atmosphere was the most favorable, while dry and cold weather retarded the process. During freezing weather operations had to be suspended.

As to the influence of dimensions on the time required for treatment, it may be assumed that the time required is directly proportional to the diameter of the log and to the square of its length. It may also be assumed as being inversely proportional to the hydrostatic pressure applied.

Timber in which the annual rings do not differ much in width, such as beech and hemlock, is more readily impregnated than timber in which the heart is much more compact than the sap-wood, as in oak. No attempt should be made to treat timber which is not perfectly sound throughout its whole section and length.

With fresh-cut beech logs intended for ties it took on an average about forty-eight hours to complete the impregnation. Logs of greater length and of other kinds required as much as one hundred hours for treatment. In cases where the impregnation was found not to be completed at the end of one hundred hours it was customary to reverse the position of the logs and to force the solution through in the opposite direction.

This process has been most extensively used in France, and to a smaller extent in Austria and Germany. In England it has never been applied, because nearly all timber used there is introduced from abroad. In the United States it has been used, so far as I am aware, in but few instances.

Yet its use insures, probably, a more thorough impregnation than any of the other methods employed at present. It does not injuriously affect the strength of the wood, and requires a comparatively small outlay for plant. It can be started almost anywhere within a short time.

Its drawbacks are that it can be carried on only during a comparatively brief season; that it takes considerable time, although less than the steeping process; and that it cannot be applied to square timber.

Considering that the large quantity of air which even fresh-cut wood contains must necessarily obstruct the passage of the solution through the log and prevent the fluid from reaching every portion of the wood; considering, moreover, that in pushing the solution through the ducts by pressure it was exposed to waste at every point where the ducts reached the surface, and that such leaks were difficult to stop, I concluded to make an experiment to see whether better results could not be attained by reversing the Boucherie process, and applying suction instead of pressure for passing the antiseptic solution through the logs. Instead of using an elevated tank, I employed two small closed vessels, in one of which a partial vacuum was kept up, while the other was being emptied of the sap and solution delivered into it by the pipe, which passed along the ends of the logs, and which was connected with the vacuum tanks, and by small rubber hose with the chambers formed at the head of each log. The caps, in this case, consisted of a thin, flexible metal ring, with sharpened edges. One edge was driven in near the circumference of the cut, and when firmly fixed, the disk, 2 to 4 inches thick, which had been cut from the end of the log to prepare it for treatment, was driven into the other edge of the metal ring. This wooden bottom of the chamber was made air-tight by smearing clay or tallow over the outside face.

A small knob fixed to the circumference of the metal ring contained a short tube, to which the rubber hose was attached by merely slipping it over the end of the tube. A cock in the short tube served to permit or to stop the exhaustion of the air from the chamber at the end of the log. The log was always placed so that the suction end was at a higher elevation than the end at which the solution entered the log. The introduction of the solution was managed in two different ways. In one, a chamber, identical with that at the suction end, was formed at the other end of the log, and the solution introduced into this chamber from a trough running along and 4 feet above the lower ends of the logs. This arrangement gave pressure at one end and suction at the other, thus greatly expediting the operation. Cuts of the fibers at the surface of the log, such as would be produced by chopping off branches, through which the air might be sucked, were readily detected and could be quickly stopped by rubbing clay or tallow into them. When the cock in the pipe connecting the suction chamber with the main pipe was opened, the first result was that the air contained in the cells of the wood was drawn into the suction chamber, and thence into the main suction pipe and vacuum tank, thus forming a vacuum inside the ducts of the log, which caused the sap and the solution from the lower chamber to follow in a solid column and gradually to fill the wood with the antiseptic solution.

Another method was to place the logs in a triangular tank in such a manner that the lower end of the log, to which in this case no chamber or cap was fixed, would be completely submerged in the solution. When the cock controlling the connecting pipe was opened the air and sap contained in the log were exhausted from it and the cells gradually filled with the solution. In some cases the tank was first filled with water for the purpose of washing out the sap before the antiseptic solution was used.

The antiseptic generally used was sulphate of copper, because its presence or absence can be determined constantly by the application of a solution of ferrocyanide of potassium, and the experiments were instituted mainly for the purpose of ascertaining how long a time was required to thoroughly impregnate the logs.

With sound logs, of 12 to 20 inches diameter, cut into lengths of 8 feet, it was found that the wood was thoroughly impregnated in from five to eight hours. This was ascertained by sawing the log in two after it had been treated and testing the whole surface of the cut with the reagent.

But when the logs were not perfectly sound the impregnation was imperfect.

A small experimental station was afterwards erected near Charleston, in Southeast Missouri, where it was intended to test the commercial value of the process, and a number of large logs, mostly Sweet Gum, were impregnated. But as this kind of timber contains a great deal of sap wood, and as most of the large logs show incipient decay at the center, the results were not nearly as favorable as those which had been attained by the previous experiments with logs cut from other kinds of timber of smaller diameter, sound and of uniform texture.

The experiments were interrupted by the illness of my son, who had charge of the work, and a season of high water, which kept the ground at the works, and for miles around, submerged for several months, induced me to discontinue the experiment altogether.

But I believe that under proper condition the method just described will cause a more thorough impregnation of wood than can be secured by any other, without the necessity of an expensive plant and without injury to the strength of the timber.

I believe also that it might be used to good advantage in works where now steeping alone is relied upon, with a view of expediting the process and of impregnating the timber not only near the surface, but also deeper. The timber, when submerged in the antiseptic solution, might be fitted at one end with a metal cap, as heretofore described, and the fluid sucked through the timber by exhausting the air and liquid from the cap. Square timber, even if of large dimensions, might thus be treated, the metal ring in that case being made of the same form as the section of the timber, and in dimension ½ or 1 inch smaller than that section. To effect complete saturation the fibers of the wood would have to be straight and parallel to the sides of the timber, but by applying the process to both ends a thorough impregnation of the inner portion of the timber would, in most cases, be obtained, while the parts near the surface would be impregnated by steeping.

In describing at such length two processes which are not used, I have been influenced by the consideration that, while neither of them can ever find general application, there are undoubtedly locations and circumstances in which preservation by a process requiring but slight outlay for plant is the only one feasible; and, so far as I am aware, a full description of these processes has never been furnished in any of the American publications treating on the subject of the preservation of timber.

(3) *Steaming.*—When fresh timber is placed in a closed vessel and steam admitted into the latter, the first effect will be to expel the air, a tap provided for that purpose being left open. When the air has been driven out this tap is closed, and, more hot steam being admitted, the temperature of the timber and of the sap contained therein rises gradually. When the temperature in any part of the timber rises to 167° Fahr., the albumen which is generally considered the ingredient in the sap most favorable to decay becomes solid. The air expands and a portion of it leaves the cells. The water contained in the cells is gradually transformed into steam, and the water of condensation, together with a great portion of the extractive ingredients of the sap, is driven from the wood and collects at the bottom of the boiler, whence it is from time to time drawn off by a tap. The steam admitted should not have a pressure greater than about 20 pounds (corresponding to a temperature of about 260° Fahr.).*

To coagulate all the albumen it is, of course, necessary that every part of the timber should be heated; but heat enters rather gradually and slowly from the surface to the interior. Experiments made by introducing Rose's metal into holes bored into the timber from the surface, which afterwards were plugged, showed that after three hours' steaming, the heat required for coagulating albumen had penetrated only to a depth of 3 to 4 inches. It is evident, therefore, that if all the albumen in the wood is to be coagulated the time during which the timber is steamed must be regulated according to its dimensions.

With timbers of considerable length and of large cross-section, it may be necessary to continue the process for six and eight hours or more.

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* It would probably be even better to restrict the temperature of the steam to 240°, or 10 pounds pressure, to prevent injurious effects to the strength of the wood where bridge timbers are to be preserved, although the process would take more time.

But such long-continued steaming will soften the fibers, weaken their coherence, and reduce the strength of the timber. Experiments made in Hanover show that the ultimate strength of Burnettized wood was reduced by one-fourth to one-tenth, and its elastic limit by one-seventh. Some part of this reduction was probably due to the action of the antiseptic used—chloride of zinc; but there can be little doubt that it was also partly due to the steaming.

Steaming has some other unfavorable features. A portion of the albumen, although coagulated, remains behind and partially stops up the cells, hinders the free circulation of steam and sap, and ultimately the entrance of the antiseptic solution. The process, moreover, does not fully remove the viscid ingredients of the sap, which, next to albumen, are most favorable to decay, while it deprives the wood completely of the essential oils and of tannic acid, which are to some extent preventives of decay; and, finally, unless the process be followed by some process of drying, as by superheated steam, and by application of the vacuum process (which will be described hereafter), it leaves a considerable quantity of water of condensation in the wood, making it incapable of impregnation with at least one of the best antiseptic substances (heavy oil of tar), and hindering complete impregnation with other preservatives.

That a considerable quantity of water remains in the wood after simple steaming, was proved by experiment, when it was found that of the water introduced into the vessel in the form of steam only two-fifths to four-fifths were removed from the boiler as water of condensation, so that from one-fifth to three-fifths remained in the wood.

(4.) *The Vacuum Process.*—In 1838 Burnett patented a method of preparing timber for receiving the preserving fluid, by placing the timber in a closed vessel and then using an air-pump for removing the air and vapor from the cells of the wood. He next filled the vessel with the antiseptic fluid, and applied a pressure as high as 150 pounds per square inch, by compressing the air above the solution. From the use of compressed air his was named the pneumatic process, and it retained that name even after the use of compressed air had been abandoned, and the pressure was directly produced by pumps.

This process, preceded by steaming and vacuum, is the one now almost universally used.

The timber to be treated is placed on cars, which are then pushed into a boiler, 6 to 8 feet in diameter, and from 60 to 110 feet long, of sufficient strength to safely bear an internal pressure of 150 pounds, and a collapsing pressure of 12 or 15 pounds. The boiler is then closed, and steam admitted under a pressure of 10 or 20 pounds. Steaming is kept up, as heretofore stated, for from three to eight hours, and is followed by exhausting the air and vapor still contained in the wood for from one to three hours, until the vacuum becomes constant on the stoppage of the pumps. The antiseptic solution is then admitted to the boiler, and when the latter is filled with the liquid, force pumps are employed to force the solution into the cells of the wood under a pressure of 100 to 150 pounds. The pressure is kept up until, on stoppage of the pumps, it remains nearly constant; say from three to sixty hours, according to quality, kind, and dimensions of the timber.

The cars with the timber on them are then removed from the boiler and a new charge introduced.

NOTE.—Many seem to be under the impression that the effect of the vacuum in drawing out the sap and air is unlimited, and the same as regards the pressure in forcing the preservative into and through the wood. We have no doubt that the vacuum and pressure are of great benefit, but to what extent the complete impregnation of the wood is affected by the amount of air that may be in the wood-cells remains to be settled by farther investigation, and more precise information would be useful. In green and rafted timber the sap is in a more or less liquid form, and the log may thus be so full of moisture as to contain a minimum amount of air, and steaming can be of benefit only by making the sap more fluid, the moisture of the steam being of no advantage. The heat also expands what air there is in the wood and thus drives out some of the moisture. With such timber it probably would be better to apply dry heat rather than by direct steaming, and thus add heat without extra moisture, for if we get a stick of timber thoroughly water-soaked, the wood-cells are full of water and there is no place into which to force the preserving fluid.—H. C.

ANTISEPTICS USED IN THE PRESERVATION OF WOOD.

Out of the great number of substances which, during the last sixty years, have been proposed for preserving wood from decay, or rather for prolonging the period of its usefulness, only four have stood the test applied, and are now employed for that purpose.

1st. Heavy oil of tar (creosote oil, dead oil).
2nd. Bichloride of mercury (corrosive sublimate).
3rd. Chloride of zinc.
4th. Sulphate of copper.

In addition to these some substances are employed for preventing the gradual removal of these antiseptics from the wood by exposure to atmospheric influences, such as chloride of tannin, glue, tannin, and sulphate of lime.

(1.) *Heavy Oil of Tar.*—The heavy oil of tar is the product of the distillation of coal-tar between the temperatures of 480° and 760° Fahr.

It generally contains from 5 per cent. to 10 per cent. of cresylic acid, the remainder consisting of heavy oil and naphthaline in varying proportions. An analysis of the oil, as imported from England and used at the works at Slidell, La., gave 9.75 per cent. of carbolic and cresylic acid, 12.50 per cent. of naphthaline, and 77.75 per cent. of heavy oil.

At 65° Fahr. it weighs about 9 pounds per gallon, and boils at a temperature of 265°. It has great antiseptic qualities, and being insoluble in water, has the advantage over all other substances used for the preservation of wood, in that when applied in proper manner, it forms a coating to the woody fiber, which prevents water and air from coming in contact with it. Being insoluble in water, it cannot be removed by immersion in water. It is, moreover, the only substance which will permanently protect timber against destruction by the *Teredo navalis* and other parasites.

Impregnation with heavy oil of tar, or creosoting, as it is sometimes called (from the fact that creosote was considered the active preservative principle), was patented in England by Bethell, in 1838.

The method of treatment proposed by him was to remove the air from the wood, to heat the oil to about 120° Fahr., and to inject it into the wood by pressure. To admit of proper impregnation, the wood should be freed from water so far as possible. In England, air-dried wood is readily procured, which being placed in a closed vessel in which a vacuum has been established, can be easily prepared for the reception of the oil. In this country, where the wood generally has to be impregnated soon after it has been cut, and when steaming has to be resorted to for driving out the sap, special means must be adopted to remove the water of condensation from the wood, after steaming, if the treatment is to be successful.

As to the quantity of oil required to preserve the wood, it may be said that the useful effect of the impregnation is proportional to the quantity of oil injected into a given volume of wood. If all the void spaces in the wood could be filled, it would take from one-half to two-thirds of a cubic foot, or from 35 pounds to 50 pounds of the oil for each cubic foot of timber. The practical limit would probably vary from 25 to 50 pounds per cubic foot, according to the kind of timber used.

But impregnation to such an extent would be altogether too expensive, and the quantity is therefore limited to what has proved by experience to be adequate for preservation under the conditions in which the wood is to be used. From 5 to 7 pounds per cubic foot is at present considered sufficient for railroad ties; about 10 pounds per cubic foot for bridge timbers; and for protecting piles used in marine structures, from 18 to 20 pounds per cubic foot are considered necessary according to the experience of American and French engineers, while English engineers consider 10 pounds per cubic foot sufficient protection for timber and piles in marine works.

The value of creosoting as a preservative against decay is shown by long experience. In England it is almost universally used for preserving railroad ties. Creosoted ties have been found perfectly sound after they had been in the ground for twenty-two years. In this country, creosoting was first applied in 1865 by Hinckley, on the Old Colony Railroad, for the preservation of piles; but the treatment was very imperfect, as the oil did not penetrate to a depth of more than one-quarter to one-half an inch below the surface. The piles were also trimmed and cut after treatment, thereby exposing untreated surfaces.

Yet in 1878, when these piles were examined, 200 of them were still found standing, although not in a sound condition. Some railroad ties (hemlock), which had been creosoted and placed in the track at the same time, were found to be perfectly sound.

Creosoted Cypress ties, which had been laid in the track of the Central Railroad of New Jersey in 1876, on an examination made in 1883 by L. L. Buck, were reported to be sound, not much worn, and in all probability good for ten or twelve years' longer service.

In 1885, Mr. J. W. Putnam examined creosoted piles and bridge timbers, which had been in use on the line of the New Orleans and Mobile Railroad for nine years, and found them all sound; the piles had successfully resisted the attacks of the *Teredo.*

Some failures are reported in this country, but in every instance they can be shown to have resulted from imperfect treatment.

Creosoting works are established at Boston, New York, Pascagoula, Miss., Slidell, La., and Bayou Bonfauca, on the New Orleans and Northeastern Railroad.

Creosoting is undoubtedly the most effective means of preserving wood, and the only obstacle to its universal introduction consists in its being more expensive than any of the other systems of preservation.

(2) *Bichloride of Mercury.*—The use of bichloride of mercury (corrosive sublimate) for the preservation of wood was patented and introduced in England by John Howard Kyan, in 1833, and was soon very extensively applied. It coagulates albumen, and is the strongest antiseptic among metal salts; it is also very poisonous. Its solution attacks iron, consequently tanks, pumps, tools, pipes, etc., for holding it must consist of wood or India rubber, or must be coated with coal-tar. It is soluble in water, and by using hot water a solution can be obtained of 1 part of bichloride of mercury and 6 parts of water. When it is to be used for the impregnation of timber the concentrated solution is diluted with the addition of water. The strength of the solutions used in impregnation has differed greatly. On the Boston railroads, where this antiseptic has been largely used for the preservation of railroad ties and sleepers, the strength of the solution was 1 part of bichloride of mercury to 150 parts of water, and the quantity absorbed by 100 cubic feet of dry pine

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NOTE.—In France all ties are impregnated, preferably with creosote, the cost per tie being as follows:

Cost of tie.	Cost of creosoting.	Total cost.
Oak .....$1 00 to $1 18	20 to 40 cents.	$1 20 to $1 35
Beech ... 67 to 77	40 to 45 cents.	1 07 to 1 20
Spruce .. 35 to 40	15 to 20 cents.	50 to 58

The average duration of ties has been found to be as follows: Oak, not impregnated, lasted on the average 14 years. Oak, creosoted, lasted 18 years. Beech, creosoted, lasted 8 to 10 years. Spruce, creosoted, lasted 12 years.—B. E. F.

wood, in the form of ties, was found to be 6.6 pounds; by 100 cubic feet of oak, 5.5 pounds; and 5 pounds by 100 feet of pine moderately dry, containing a large amount of resin.

On the Eastern railroads the strength of the solution at first was 1 in 240 parts, and at present a solution of 1 in 99 is used. The timber is said to absorb about 2.6 pounds per cubic foot, while Mr. J. B. Francis states that in the Lowell works the wood is found to absorb about 6 pounds of sublimate per 100 cubic feet. In England solutions have sometimes been used containing 1 pound in 46, but without securing as good absorption as was obtained with weaker solutions, since only 2.2 pounds per 100 cubic feet were attained, it being probable that some of the sublimate was precipitated in the pores near the surface, stopping them sufficiently to partly prevent the entrance of the solution to the inside of the wood.

The impregnation of wood with corrosive sublimate has always been carried on by steeping. In Germany wooden tanks, from 20 to 35 feet long and from 4 to 5 feet in height, are used. The rule observed as to the length of time of immersion has been to leave ordinary railroad ties ten days in the tanks, lumber five days, bridge timbers fifteen days. In some works the rule is to steep pine ties for eight days, and oak ties for fourteen days.

At Lowell, Mass., where this process was introduced by Jas. B. Francis, C. E., in 1848, and has been carried on (with an interruption of twelve years, 1850 to 1862) up to this time, the steeping is performed in wooden tanks 50 feet long, 7½ feet wide, and 4 feet deep. The rule laid down by Mr. Francis for the duration of steeping is, that the timber should be kept immersed a length of time depending on its least thickness, one day being allowed for each inch in thickness, and one day in addition, whatever the thickness. This makes the time of immersion for a 6-inch timber seven days. At the works of the Eastern Railroad at Portsmouth, Me., tanks 69 feet by 9½ wide, and 6 feet deep, built of granite laid in cement, are used. The inside of these tanks is coated with coal-tar, applied hot. Ties 6 inches thick, according to H. Bissell, M. M. W., Eastern Railway, require one week; 12-inch timber, two weeks. The time of immersion is, therefore, nearly the same at all works. The difference in the quantity of sublimate absorbed (2.6 pounds per 100 cubic feet at Portsmouth, against 6 pounds per 100 cubic feet at Lowell and in Germany) could be due probably only to the fact that the timber treated at Portsmouth was not air-dried.

Bichloride of mercury being a very active poison, great care in handling it is plainly indicated. In Baden it was considered necessary to take extra precaution against the poisoning of the workmen, and some prejudice was created against this mode of preservation on this account; but the experience in this country on this point is somewhat reassuring. Mr. Francis states that, in an experience in Kyanizing, extending over more than thirty years, he has known no case where the men operating with it have been made ill. He says that men working over the tank in which the corrosive sublimate was being dissolved in hot water sometimes complained, but that he never knew any man to be seriously affected. He mentions, however, that in Kyanized timber an efflorescence of the sublimate has sometimes been observed, which might be injurious to cattle, if licked off from timber to which they have access. This might be prevented to some extent if the precaution used in Germany was adopted, of washing with hot water the surface of the timber when treated, and before being exposed. Mr. Bissell corroborates the statements of Mr. Francis. He states that the man in charge of preparing the solution has, in a few instances, been nauseated for a short time by inhaling vapor arising from the solution; but that he believes this would have been prevented by a little more carefulness, and that the men handling the timber never suffered any injury, although frequently careless.

The testing of a solution of the sublimate, as to its strength, can readily and accurately be performed. A graduated test tube being filled with it, a solution of iodide of potassa is added, which precipitates the oxide of mercury as a red powder, which by the further addition of the solution of iodide of potassa is again dissolved, so as to leave a clear liquid. The change in color can be accurately observed, and the numbers on the graduated test tube can be so arranged that the man in charge can read off the weight of bichloride of mercury to be added to bring the solution to its proper strength.

There is ample testimony as to the efficiency of bichloride of mercury as a preservative of wood. The railroad ties of the Baden Railroad, impregnated with it, lasted from twenty to thirty years. Mr. Francis states that in 1850 he put up a fence of Kyanized spruce lumber, which is still perfect, not a single piece having been removed during the thirty-five years, and only part of the wood which was under ground having decayed. The Pawtucket Street Bridge, built in 1849 of northern White Pine (Kyanized), did not require any repair until 1882, a period of thirty-three years. Kyanized timbers were used in nine spans of the Burr truss bridge, at Georgetown, which stood from 1840 to 1862, and failed, not from the decay of its timbers, but from bad construction. The Blackstone River Bridge, on the New York and New England Railroad, a Pratt truss built of Kyanized timber in 1848, when taken down in 1876, after twenty-eight years' service, was found but slightly decayed. Two bridges on the Philadelphia and Reading Railroad, built in 1850 of Kyanized timber, proved sound after twenty years.

The experience in this country as to Kyanized ties is not as favorable as in Baden. This may be due to two causes. On the Baden Railroad the ties and all other timbers are air-dried during two or three weeks after impregnation and before being laid, which precaution is probably not observed in this country, and the road-bed in which the ties of the Baden Railroad were laid consisted of a very dry gravel, which allowed all rain-water to run off at once. But even on other German roads the success of Kyanizing has been remarkable, and the failures which are recorded were due in many cases to imperfect impregnation.

Still, from the experiments of Mr. Francis, it seems to be certain that Kyanizing will give better results when the timber is exposed to air than when placed underground. This results very likely from the sublimate being gradually dissolved and washed out. It might be prevented probably by first drying the treated timber and then giving it a coating of dead oil, on the ends at least.

(3) *Chloride of Zinc.*—The use of chloride of zinc for the preservation of timber was patented by Burnett, in England, in the year 1838.

Chloride of zinc is prepared by dissolving metallic zinc in hydrochloric acid. In its most concentrated form it contains 32 per cent. of zinc, but generally only 25 per cent. The specific gravity of a solution of this strength is about 1.6. It is sometimes made from zinc skimmings, and is then liable to contain free hydrochloric acid and chloride of iron; the first, like nearly all free acids, reduces the strength of the timber, while the second reduces the value of the solution as an antiseptic.

Chloride of zinc has the greatest affinity for wood fiber, and is hygroscopic, both being qualities which increase its value as a preservative. It is also a very strong antiseptic. Burnett at first recommended to use a solution of 1 part (by volume) of concentrated chloride of zinc to 59 parts (by volume) of water. In Germany stronger solutions were frequently used, 1 in 30, 1 in 24, and in one case even 1 in 14 parts. But it was found, as in the case of corrosive sublimate, that by using these stronger solutions the quantity of zinc absorbed by the wood was not proportionally increased, because such solutions would not so readily enter the cells, and that some portions of the timber received an excessive amount of the zinc chloride, while others received little or none. The presence of an excess of chloride of zinc, moreover, seems to injure the fiber, causing brittleness in the wood, and to prevent these consequences the strength of the solutions on German railroads has been reduced to 1 in 50, or 1 in 60.

In this country solutions of 2 in 100 and 3 in 100 were used at first (Erie Railway Company). On the Philadelphia and Western Railroad the solution used contained 5 or 6 in 100; on the Philadelphia and Reading Railroad, 3¾ in 100; on the Havre de Grace Bridge, 1.12 in 100. At present the solutions generally used have a strength of 1.9 or 2 in 100. The strength of solutions is generally measured by the areometer; but the specific gravity of the solutions of zinc chloride changes so rapidly under changes of temperature that errors are unavoidable, unless proper corrections for temperature are made.

The weight of concentrated chloride of zinc, which was absorbed from a solution of a strength of 1 in 60, was found to be as follows on the railroads of Hanover, Germany:

100 cubic feet of Oak absorb 22 pounds of concentrated chloride of zinc.

100 cubic feet of Beech absorb 106 pounds of concentrated chloride of zinc.

100 cubic feet of spruce absorb 50 pounds of concentrated chloride of zinc.

At the works lately built at Las Vegas, N. Mex., with a solution containing 1.5 parts of concentrated chloride of zinc in 100 parts (by volume)—

Hewn ties absorb 33 per cent. of solution (by volume), or 49 pounds of concentrated chloride of zinc in 100 cubic feet.

Sawed ties absorb 17 per cent. of solution (by volume), or 24 pounds of concentrated chloride of zinc in 100 cubic feet.

Piles 40 feet long, 17 inches at the butt, 12 to 14 per cent., or 16 pounds of concentrated chloride of zinc in 100 cubic feet.

With a solution of a strength of 2 in 100, the absorption would be 75 pounds, 32 pounds, and 21 pounds per 100 cubic feet, respectively.

The efficiency of the chloride of zinc in preserving wood is well attested.

On roads in Hanover 169,000 ties (Burnettized oak) lasted, on an average, 19.6 years.

On the Rhine Emden Railroad 161,515 Burnettized Fir ties lasted, on an average, 22.8 years; 81,000 Beech ties, on the Hanover Railroad, lasted, on an average, 14.8 years; while, when left untreated, the average duration of oak ties in Germany is 14 to 16 years; of fir ties, 7 to 8 years, and of Beech ties 2½ to 3 years.

As to the success of this mode of preservation in this country, the following facts may be mentioned: Of 2,000 Burnettized ties laid on the Chicago, Rock Island and Pacific Railroad in 1866 (pine, Tamarack, and cedar, and the greatest part Hemlock), when examined in 1881 by M. Alexander, roadmaster, 75 per cent. were still found present in the track, and in such condition that they might do good service for 2 or 3 years longer.

L. L. Buck reports that in 1882 he examined a lot of Burnettized ties laid in 1866 and 1868, consisting of Maple, Beech, and Hemlock, and found them, with few exceptions, in a good state of preservation, and more particularly the Hemlock ties. He expresses the opinion that, although in the ground for 16 years, they would probably last from 7 to 8 years longer.

R. M. Chaffee, president of the Union (horse) Railroad at Cambridge, Mass., states that of a lot of Burnettized spruce sleepers laid in that railroad, many were found in good condition after 28 years' service.

A truss bridge of 8 spans, built for the Chicago, Rock Island and Pacific Railroad of Burnettized timber in 1860, was still in fair condition in 1882.

Where Burnettizing failed, it was due to improper treatment. The fact alone that 22 out of 48 German railroad companies, who preserve their ties, use this antiseptic might be accepted as a proof of its efficiency as a preservative.

(4) *Sulphate of Copper.*—Sulphate of copper (blue vitriol) had long been known as a strong antiseptic; but was first used for the preservation of wood by Boucherie, in the year 1838. When used for this purpose it should be free from deleterious admixtures, among which the most common, and at the same time most injurious to wood, is sulphate of iron; for sulphate of iron is easily decomposed, and the free sulphuric acid resulting therefrom attacks and weakens the wood fiber.

The solution of sulphate of copper recommended by Boucherie consisted of 1 part (by weight) of sulphate of copper to 100 parts (by weight) of water.

The increase of timber in weight by impregnation with sulphate of copper was found by Boucherie, when his method of treatment was used, to be as follows per 100 cubic feet: pine, 140 pounds; oak, 145 pounds; Hemlock, 320 pounds; Beech, 540 pounds.

But this increase in weight does not express the weight of dry sulphate of copper taken up by the wood, nor the weight of the diluted solution of sulphate of copper absorbed.* The weight of dry sulphate of copper absorbed by Beech was found to be 32 pounds in 100 cubic feet of wood, and this is the weight of dry sulphate of copper which 100 cubic feet of this kind of wood is required to contain (1.1 pounds per tie of 3.5 cubic feet), under the specifications of the French engineers.

When the Boucherie process of impregnation is used, the weight of sulphate of copper required per cubic foot may be set down at 40 pounds per 100 cubic feet, to make allowance for loss in antiseptic resulting from his mode of treatment. Impregnation with solutions of sulphate of copper has been carried on by almost every known method of treatment, viz: by steeping, by the Boucherie process, and by vacuum and pressure.

One disadvantage in the use of this antiseptic consists in the fact that boilers, pipes, pumps, and tools used in carrying on the process must consist of copper, because contact with iron decomposes the sulphate of copper. This, of course, largely increases the cost of the necessary plant.

Another respect in which treatment with sulphate of copper is inferior to treatment with chloride of zinc, at least in preserving railroad ties, may be found in the fact, that when ties treated with sulphate of copper are placed in the track, the iron rails and spikes coming into contact with the sulphate of copper will decompose the latter, producing free sulphuric acid, which attacks the fiber and injures the strength of the timber. In some cases the endeavor has been made to prevent this by covering the ties, where they touched the rails, with coal tar, and by using galvanized spikes. Sulphate of copper is less hygroscopic than chloride of zinc, and ties treated with it are more liable to crack.

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* Boucherie found that in 23 hours 3,050 liters of solution entered into a Beech log 15 meters long and averaging 0.9 meters in diameter, or about ⅓ of its total volume.

There is one point, however, in which it is superior to chloride of zinc, and which is of very great importance, when the treatment is to be effected under contract. While it is difficult to control the strength of a solution of chloride of zinc used in impregnation, or to find by chemical analysis the actual quantity of zinc contained in the timber after impregnation, both of these operations can be performed with great accuracy, and without much expenditure of time or money, when sulphate of copper is used. There can be less cheating, and, therefore, the success of the treatment as a means of preservation is more fully assured. To show the efficiency of the sulphate of copper in prolonging the life of wood, it may be stated that, according to German experiments, 60,000 fir ties which had been merely steeped in a solution of sulphate of copper lasted on an average 13.9 years; that 36,000 ties of the same kind of timber, which had been boiled in a solution of this same antiseptic, and laid on the Berlin, Potsdam and Magdeburg Railroad, lasted on an average 14 years; and that 111,000 fir ties, impregnated with sulphate of copper under pressure, averaged 16 years of usefulness; while unimpregnated fir ties used in the same railroads lasted only from 7 to 9 years. It may, therefore, safely be assumed that the durability of such ties would be doubled by proper treatment with sulphate of copper.

The use of sulphate of copper has been nearly abandoned in France, but is still carried on by some of the German railroads.

In this country it has been used only in connection with the Thilmany process, which will hereafter be described. One obstacle to its use may have been found in the fact that sulphate of copper formerly cost much more than chloride of zinc; but the price of copper has declined so much of late that the difference in cost has been greatly reduced.

NOTE.—The outfit for the Boucherie process is light and inexpensive, as well as that for Kyanizing, consisting of tanks in which to mix and store the preserving liquid and troughs to receive the sap; or, with the latter process, tanks in which to soak or steep the timber. The Burnettizing process and the Bethell process must prepare the wood by steaming, etc., and require iron cylinders, a steam boiler, and pumps. But the usual form can be modified, as Colonel Flad has indicated, by using two or more smaller cylinders with boiler and pumps, all attached to trucks or arranged to be easily handled, and with all pipe connections so arranged as to be made or broken readily.

The advantages of a movable plant have received less attention and have been tested less than they deserve. The transportation of timber is of course a considerable item of expense. A plant of moderate size could be taken to the various sources of supply from which the timber comes or to the most economical distributing points, and thus the cost of transportation, in one direction at least, would often be saved.—H. C.

METHODS AND SUBSTANCES USED TO RETAIN ANTISEPTICS.

The heavy oil of tar, being insoluble in water, will not be removed from timber which has been impregnated with it, even if the timber is permanently submerged in water. But the metallic salts at present used in wood preservation, bichloride of mercury, chloride of zinc, and sulphate of copper, being injected into the wood in the form of aqueous solutions, are of course liable to be dissolved again by moisture and eventually to be removed when the timber is exposed to the action of water. Experiments made by chemists seem to prove that a portion at least of the sulphate of copper and of chloride of zinc combines with the fiber of the wood and cannot be removed again; but all that has not been fixed by such combination may, in the course of time, be removed from the wood when permanently immersed in water. Metallic salts should, therefore, not be used when wood is exposed to the constant action of water, and it would be desirable to adopt means for preventing even the gradual, but much slower, removal of the salts by rain and moist air, although the favorable results with wood which had not received such extra protection leaves some doubt as regards its economical value.

The methods which are now used for preventing the "washing out" of the metal salts are: (1) The Thilmany process; (*a*) with sulphate of copper; (*b*) with sulphate of zinc. (2) The Wellhouse process. (3) The zinc-gypsum process. (4) The zinc-creosote process.

1. *The Thilmany Process.*—Thilmany, in 1869, took out a patent for a method of preservation by which the wood was first to be impregnated with sulphate of copper and then to be immersed in a bath of chloride of barium. An interchange of the constituents of these two salts, if brought together in the proper proportions, would leave the timber impregnated with chloride of copper and sulphate of barium, which latter, being insoluble in water and in all acids, was expected to fill up the pores of the wood so as to prevent the removal of the chloride of copper by water entering from the outside.

The process was first tried at Cleveland, Ohio, with blocks for wood pavement. As far as I am informed, the wood was treated with sulphate of copper by the Boucherie process and then immersed in a bath of chloride of barium. In 1881 I took up and examined some of the elm-wood blocks which had been thus treated and laid down in Saint Clair street in 1870, and found them perfectly sound after eleven years' exposure on the street.

Works were erected at Defiance and Milwaukee, where the timber and ties were treated with the Thilmany preservatives by steaming, vacuum, and pressure. But the results were not very favorable. At Defiance a solution of 1.5 in 100, and later one of 2 in 100, was injected with a pressure of 80 to 100 pounds until all the pores of the wood (as Mr. Thilmany says) were charged with the solution, when the boiler was filled with a

1½ per cent. solution of chloride of barium. It is hard to conceive how the second solution could enter the pores already filled with the solution of sulphate of copper, and where the chloride of barium reached the first solution it left chloride of copper, the value of which as an antiseptic is uncertain, and some sulphate of barium inside of the wood, which could do neither good nor harm. The treatment of the paving blocks at Cleveland was evidently more rational, because by the Boucherie process the wood was well impregnated with sulphate of copper, and the soaking in chloride of barium only produced an interchange near the ends, where the formation of the insoluble sulphate of barium was of the greatest benefit in stopping up the pores to some extent, and if not preventing, at least impeding, the ingress of water and the washing out of the sulphate of copper from the inside.

Mr. Thilmany later used sulphate of zinc, instead of copper, in connection with chloride of barium, but the process does not appear any more rational. If the interchange of the chemicals throughout the lumber could occur, it would leave the wood impregnated with chloride of zinc and sulphate of barium; but as such a complete interchange is impossible, part of the sulphate of zinc would undoubtedly remain unchanged, and as its antiseptic powers are not established, the result as to preservation must be uncertain.

2. *The Wellhouse Process.*—Another device for preventing the remova of the zinc chloride has been invented by Mr. Wellhouse and is extensively used. It is based on the fact that glue and tannin, brought together in proper proportions, will form a substance resembling leather. The timber is steamed in the usual manner, inclosed in a vacuum, then impregnated by pressure with a solution consisting of chloride of zinc and glue, and afterwards subjected to a bath of tannin under pressure. The impregnation with glue, it is claimed by the president of the company using this process, will destroy all tannic acid within the wood. But the benefit derived from this chemical combination is not apparent, since tannin is rather a preservative than otherwise. The bath of tannin, the president further states, precipitates the glue remaining in the outer pores of the wood, retaining a greater percentage of chloride of zinc in the wood than would be the case if it were simply Burnettized. But while the latter claim may be substantially correct, it remains to be seen whether the introduction of an uncombined organic substance into the inside pores will prove favorable to preservation.

The question whether the zinc tannin process gives better results than the ordinary Bethell process will be decided within a few years, as a number of works for treating ties by this process have lately been constructed by the Atchison, Topeka and Santa Fé Railroad at Las Vegas, N. Mex., and by the Union Pacific Railroad at Laramie, Wyo., and the process is also used for preserving ties for several railroad companies at the Chicago works of the company.

The works, at Santa Fé, which have within a year been erected on the plans and partly under the supervision of Mr. O. Chanute, C. E., are constructed and operated in accordance with all the requirements of the best modern practice. At the Las Vegas works an accurate and full record is being kept of all the operations and of all expenditures, more complete than has ever been approached, so far as I know, in this or probably any other country, and which, when published in full, will give more trustworthy information as to the cost of wood preservation than has heretofore been obtainable.

The data contained in these reports, which have been kindly furnished to me through Col. Edgar T. Ensign, forestry commissioner of Colorado, have been very useful in determining the comparative cost of the several processes now in use for the preservation of wood.

Whether the use of glue and tannin in connection with the zinc chloride will prove a success or not, the works erected under Mr. Chanute's directions, and the methodical system of operating them initiated by him, will do as much for the proper preservation of timber by mineral salts as Andrews, at Boston, and J. W. Putnam, in the South, have done for the proper application of the creosoting process.

3. *The Zinc-gypsum Process.*—The process was patented by Mr. Hagen, of Saint Louis, and is used by the American Wood Preserving Company. In this process the timber is impregnated with a solution containing both chloride of zinc and gypsum. When the water of the solution evaporates the gypsum crystallizes and is expected to stop up the pores of the wood, and thus prevent the washing out of the zinc-chloride. The question arises, whether a substance soluble in water to some extent like gypsum can be expected to permanently stop up the pores of the wood against the ingress and egress of water. It seems hardly possible that the gypsum would answer the purpose. The best that can be said for this process is, that if the addition of gypsum does no good it cannot do harm, and that if the wood is impregnated thoroughly with a solution of chloride of zinc and gypsum it will last as well at least as wood simply Burnettized.

4. *The Zinc Creosote Process.*—A process has lately been proposed by Mr. Jas. T. Card, President of the Wood Preserving Works at Chicago, Ill., viz: To impregnate the timber first with chloride of zinc, and after partially removing the moisture from the wood to inject dead oil through the outer portions of it, thereby securing, as Mr. Card states, "all the benefits derived from the oil when lumber comes into contact with the ground, as well as insuring thorough treatment of the wood, through chloride of zinc, which is protected by the oil surrounding it, thus preventing its being chemically changed or washed out."

The process seems rational, and would probably answer a good purpose, if the necessary time and money can be spared to thoroughly dry the timber after impregnating it with zinc chloride. and before injecting the oil.

COST OF PRESERVATION.

In order to make a fair comparison of the cost of treatment with the different antiseptics now in use, I will assume that the same kind of timber and the same form, viz, that of hard railroad ties, each containing 3.5 cubic feet, is to be treated, and that the quantity of antiseptic solution used, and the strength of the solution, are to be in conformity with the best practice, as developed by experience in plants of given size.

a. Creosoting.—Assuming that two injection cylinders are to be used, each 100 feet long and 6 feet in diameter, the total volume of each cylinder will be 2,800 cubic feet, and it will have a capacity of nearly 1,400 cubic feet of timber (making allowance for volume of cars and interstices). The total plant required would cost, say, $80,000. If it takes twelve hours for a run, 5,600 cubic feet, or 1,600 ties (of 3.5 cubic feet each), can be treated per day; or, say, 500,000 ties, or 1,750,000 cubic feet, can be treated in a year.

Taking the interest on capital (including repairs and renewal) at 10 per cent., the item of interest on plant will be $8,000, or 1.6 cents per tie.

Assuming the proper quantity of dead oil at 7 pounds per cubic foot, or 24.5 pounds per tie, and the cost of the oil at 0.8 cents per pound, the cost of material will be 19.6 per tie.

The cost of labor and fuel chargeable to treatment alone, judging from the accounts kept at Las Vegas, may be taken at about $15 per run, or, as 400 ties are treated at once, 3.75 cents per tie, or 1.07 cents per cubic foot of timber. The total cost of creosoting a tie would be, therefore:

	Per tie.	Per cubic foot.
	Cents.	*Cents.*
Interest on capital..	1.6	0.46
Material	19.6	5.6
Labor and fuel......	3.75	1.07
Total	25.00	7.1

The cost of transporting the ties to and from the works would of course have to be added, and profit, if the work is done by contract.*

I may mention, that the above price for the dead oil is smaller than has been generally assumed, this because lately I have been offered dead oil at ⅓ of a cent per pound. At that price the cost of creosoting would be only about 14½ cents per tie.

If piles or timber were to be creosoted and impregnated with 20 pounds per cubic foot, it would take about sixty hours for a run, and the total number of runs per annum would be 240 (with 2 cylinders); the number of cubic feet of timber treated per annum, 350,000; the labor and fuel per run, $60, and the total cost of treating 1 cubic foot of timber: Interest on plant, $\frac{8000}{350000}$=2.3 cents per cubic foot; material (20 pounds at 0.8 cents), 16.0 cents; labor and fuel, 4.3 cents; total, 22.6 cents, or about $19 per 1,000 feet B. M.

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* See note of cost of creosoting in France on page 78.

b. *Kyanizing.*—If the impregnation is to be carried out in the ordinary way, by steeping, and if the works are to be of sufficient capacity to treat 250,000 ties per annum, or, say, 800 ties, equal to 2,800 cubic feet of timber per day, and if the steeping is to be continued for 7 days, there must be tank-room for, say, 20,000 cubic feet of timber. Allowing 1.3 cubic feet of tank-room for 1 cubic foot of timber, the total capacity of the tanks required will be 26,000 cubic feet, and if tanks 50 feet long, 7.5 feet wide, 5 feet deep are used, about 14 tanks will be required.

The plant would cost probably $10,000, and on 250,000 ties the charge for interest on plant would be (at 15 per cent. in repair and renewal) 0.6 cents per tie.

If 0.06 pound of bichloride of mercury is used per cubic foot, or 0.21 pound per tie (of 3.5 cubic feet), and the sublimate costs 50 cents per pound, the cost of material is 50 x 0.21=10.5 cents per tie. Labor and fuel would be about 3.5 cents per tie, and the total cost of Kyanizing:

	Per tie.	Per cubic foot.
	Cents.	*Cents.*
Interest on capital	0.6	0.17
Material	10.5	3.00
Labor and fuel	3.5	1.00
Total	14.6	4.17

Bridge timber would have to be steeped during two weeks, instead of one, and as, therefore, only half so much lumber could be treated as in the case of ties, the interest on capital would be doubled, the cost of material and labor remaining the same; the cost of treatment per cubic foot would, therefore, be increased only about one twenty-fifth, and would be 4.34 cents per cubic foot.

c. *Chloride of Zinc.*—If ties are to be impregnated by steaming, vacuum, and pressure, the cost of plant required (in connection with two injecting reservoirs) is about $40,000. Assuming the time used for one run at 10 hours, 60 runs could be made per month with each cylinder, or 120 runs with the two cylinders, or 1,450 runs per annum. Taking 400 ties per run, the total number of ties which could be treated in a year would be 580,000, equal to, say, 2,000,000 cubic feet of timber. Allowing 10 per cent. interest on cost of plant will give $4,000, or $\frac{400000}{580000}$=0.69 per tie, or 0.2 per cubic foot. The cost of concentrated chloride of zinc (specific gravity 1.5) is about $2.60 per cubic foot. If the solution has a strength, 1 in 60, 1 cubic foot of it will cost 4.3 cents, and if the wood takes up 33 per cent. (by vol.) of the solution per cubic foot, it will require $\frac{1}{3}$ cubic foot of the weak solution, costing 4.3, $\frac{260}{180}$=1.44 cents per cubic foot of lumber, or 5 cents per tie. Labor, at $10 per run, will cost $14,500 or 0.72 cent per cubic foot, or $2\frac{1}{2}$ cents per tie. The total cost of this mode of preservation will, therefore, be:

	Per tie.	Per cubic. foot.
Interest on plant	0.69	0.2
Material	5.04	1.4
Labor and fuel	2.52	0.7
Total	8.25	2.3

d. Zinc Tannin.—If, in addition to chloride of zinc, glue and tannin are used, the cost of material is increased by 2.5 cents per tie, and the cost of labor and fuel $\frac{1}{5}$, or 0.5 cents per tie, making the total cost 11.25 cents per tie, or 3.2 cents per cubic foot.

e. Sulphate of Copper.—If a solution of sulphate of copper, 1 in 100, was to be injected by the same process, the change in cost would be in interest on plant and cost of material. As such works would cost about $60,000, the item of interest would be increased by one-half. As to cost for materials, sulphate of copper can now be bought at 7 cents per pound. Adding 99 pounds of water, 100 pounds, or 1.5 cubic feet of, the solution will cost 7 cents, or 1 cubic foot, 4.6 cents.

Again, if one-third cubic foot of the solution be injected, the cost of material per cubic foot of wood will be 1.5 cents, and the cost per tie, 5.25 cents. The total cost of preservation would then be:

	Per tie.	Per cubic foot.
Interest	1.05	0.3
Material	5.25	1.5
Labor and fuel	2.5	0.7
Total	8.80	2.5

f. Solutions of Chloride of Zinc, or Sulphate of Copper, injected by the Boucherie Process.—To treat 800 ties per day with zinc direct (pressure) by the Boucherie process, would require an investment of capital of about $5,000. The interest on this sum, at 20 per cent. (including repairs and renewal), would be $1,000, or on 250,000 ties, 0.4 cents per tie.

The quantity and cost of the chloride of zinc and sulphate of copper would be the same as when treated by the modern process, plus one-quarter for loss of solution from treating round sticks and from leakage. The labor would be $3\frac{1}{2}$ cents per tie, and the total cost:

ANTISEPTIC.

	Chloride of zinc.	Sulphate of copper.
	Per tie.	*Per tie.*
Interest	0.40	0.40
Antiseptic	6.25	6.56
Labor	3.50	3.50
Total	10.15	10.46

If the impregnation is to be produced by suction, the cost of plant will be $12,000, the cost of the antiseptic the same as before, and the cost of labor also the same, since, although it requires two men to attend to the same number of logs which one man can attend to in the direct Boucherie process, the treatment is completed in half the time.

The cost of preservation by this method is, therefore, as follows:

ANTISEPTIC.

	Chloride of zinc.		Sulphate of copper.	
	Per tie.	Per cubic foot.	Per tie.	Per cubic foot.
Interest, repairs, and renewal, 20 per cent.	0.96	0.28	0.96	0.28
Antiseptic	6.25	1.80	6.56	1.90
Labor	3.50	1.00	3.50	1.00
Total	10.71	3.08	11.22	3.18

Recapitulation of cost of preservation of railroad ties with different antiseptics and methods.

[Volume of ties, 3.5 cubic feet.]

Antiseptics.	Method of treatment.	Total cost.	
		Per tie.	Per cubic foot.
1. Dead oil	Modern method	25.00	7.13
2. Bichloride of mercury	Steeping	14.60	4.17
3. Chloride of zinc	Modern process	08.25	2.30
4. Chloride of zinc and tannin	Modern process	11.25	3.20
5. Sulphate of copper	Modern process	08.80	2.50
6. Chloride of zinc	Direct Boucherie	10.15	2.90
7. Sulphate of copper	Direct Boucherie	10.46	3.00
8. Chloride of zinc	Boucherie (suct.)	10.71	3.08
9. Sulphate of copper	Boucherie (suct.)	11.22	3.18

As before stated, these estimates do not embrace the hauling of ties to and from the works. If the ties are destined for a new road just built, the preservation of ties by processes 2, 6, 7, 8, 9, in which the plant can be moved from one place to another, saves the carrying of the ties to distant works for treatment. No. 2, however, requires seasoned wood, and does not, therefore, offer as great advantage as the others. The entire cost of this transportation might, in some cases, amount to 5 or even 10 cents per tie.

CONCLUSION.

By Howard Constable, C. E.

The practicability and economy of wood-preservation have been brought in question often, because the processes have been conducted by dishonest contractors or have been based upon some unwarrantable theory rather than upon any scientific principles. Nevertheless many successes have been achieved, and improvements have been made in the details of treatment and in mechanical contrivances to meet the conditions peculiar to this country. The follwing table* of experiments, in addition to those mentioned by Col. Flad, is certainly encouraging.

Both here and abroad the durability of wharf and other timber subject to severe exposure has been and can be at least doubled. The durability of piles and other timber subject to the attacks of the sea-worm *Teredo* can be prolonged three or four times. The possible economy resulting from the use of treated Hemlock ties, instead of White Oak in their natural condition, has been estimated by Mr. O. Chanute as follows: For a road with about 2,000 miles of track, containing about 5,000,000 ties, $250,000 in first cost every twelve years, and $250,000 each year in the average charge for renewal of ties. Some moderate-sized roads use as many as 400,000 ties a year, and have to get from one-quarter to one-half of them from other territory than their own, which, of course, results in the railroads putting great obstructions to the shipping of ties out of their own region, and necessitates going to great distances for the extra supply.

A few are familiar with all these facts, but the majority, and the economists or business men, frequently realize them only partially, and do not appreciate the importance of the subject to themselves. We shall be accomplishing much if we aid in giving these persons a comprehensive and clear idea of it in its general bearings.

One of the first things to be clearly understood is that the field of wood-preservation is a very large one, embodying many natural and artificial conditions somewhat different in each particular locality and case. Every one cannot preserve wood with advantage. It cannot yet be done cheaply enough for ties on a new road in a heavily wooded district, any more than we could use stone for depots in such a region

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* See p. 98.

Nor is there any "cure-all" process by which any wood for any and every purpose can be preserved. Piles, which are cut to pieces by the *Teredo* within two years, require different treatment from ties to be placed in an ordinary road-bed, as the method of handling and transporting perishable freight must differ from that of ordinary freight, necessitating more care and expense. Any system to be adapted to a variety of work and to give promise of economical results must have the harmonious co-operation of all concerned in its operations and faithful attention to details. Each one in any way connected with the work should have a general understanding of it, and a precise knowledge of his own particular duties and the limits to be observed. If this is not the case the purchasing agent may contract for timber quite unsuited to the purpose for which it is procured; the superintendent may overlook the importance of ample facilities of operation; the engineer may not comprehend the degree of treatment required, and the inspector and workmen may become careless and so ruin the work.

The need of intelligent co-operation is here emphasized because it has been neglected frequently and caused processes in themselves good to be attended with unsatisfactory results.

If a business man—the president, perhaps, of some company—thinks the subject of wood-preservation may have in it some benefit for him, or those whom he represents, his main inquiries are, What does it amount to? Will it pay? Will it make a conspicuous item of economy? How will it affect our policy and dealings with others? Is it practicable in our case?

The manager asks somewhat the same questions, but inquires further, What are the conditions and necessities in our case? What is the best process and its cost? What are the conditions for success? What facilities have we? What rules shall be laid down?

The engineer or foreman in charge wishes to know what precisely is the composition of each ingredient, what is the order and time of each step in the process, what are the requisites and facilities. and what standard must be exacted in order to insure success.

Thus it becomes plain how the physical and commercial divisions of the subject interlace and require to be in accord. In order to select a process and lay down rules for the guidance of all connected with it, it is necessary to decide what purpose and exposure the wood is to be subject to, then to ascertain accurately all the conditions which prevail in the special case, and to determine the length of life that should be secured. Questions like the following will come up naturally and almost necessarily for answer: What is the name, quality, and cost of the wood to be used; its use and exposure; nature of soil and water; average length of life; sources of injury, such as *Teredo*, notching and framing, cutting by the rail, etc.; destroyed by what? Cost of renewals. Available woods for treatment. Cost of the same. Probable quality and condition. Receiving point. Distributing point. Location for preserving-works. Capacity of plant. Cost of plant. Cost of operating.

I may be permitted to quote from the recent and very instructive report on the preservation of timber, made in 1885, by a committee of the American Society of Engineers, after a careful and protracted examination of the subject:

"In view of the differing cost of the various antiseptics used, and of the price of timber in this country, where it is still much cheaper than in Europe, we believe that the method to be selected for preserving wood, if any, depends almost wholly upon its proposed subsequent exposure.

"If the timber is to be exposed, in sea water, to the attacks of the *Teredo navalis* and *Limnoria terebrans*, there is but one antiseptic which can be used with our present knowledge. This is creosote or 'dead oil,' and the amount of it necessary depends upon the activity of the *Teredo*, or rather upon the length of time during the year when the temperature of the water renders them active.

"In our northern harbors, probably 10 to 12 pounds of creosote to the cubic foot of timber are sufficient, but in southern seas it is probably necessary to inject from 14 to 20 pounds per cubic foot.

"Whether it will pay to do this depends upon so many local circumstances in each case that this cannot well be discussed here. If the timber is to be exposed in a very wet situation, creosoting is also the best process to use. It will cost from $10 to $20 per 1,000 feet, b. m., or 35 to 60 cents per tie.

"The selection of the oil, as well as the quantity, is of importance. It was formerly believed that the antiseptic properties of dead oil arose from the presence of carbolic and cresylic acid, but a very able paper by Mr. S. B. Boulton, the leading authority on creosoting in England, read before the British Institution of Civil Engineers in 1884, seems to establish the fact that the preserving properties of dead oil, aside from the mechanical effect in keeping out moisture, are chiefly due to 'acridine,' or one of the alkaloids or bases now known to exist in creosote oils.

"If the exposure is to be that of a railroad tie, creosoting is doubtless the most perfect process to use; but in view of the expense, it may be preferable to use a cheaper process, dependent somewhat upon the location, as away from the seaboard creosote is not available, and transportation is expensive."

"Sleepers of Baltic Fir, unprepared, 9 feet long and 10 x 5 inches, generally cost, in England, about 90 cents each, unloaded, grooved, and piled; and creosoting adds about 24 cents to this. So that the sleeper costs about $1.14 ready to go into the track, and is there laid with a chair under the double-headed rail, so that the latter does not cut into the wood. These sleepers, therefore, last 18 to 20 years, while in this country they would probably be cut into by our foot-rail in from 12 to 16 years; and, moreover, as the first cost of our ties, of corresponding timber, say hemlock or mountain pine, is only from 25 to 35 cents, we cannot afford to spend an equal sum in preserving them; and creosoting is notoriously more expensive here than in England.

"With our present knowledge, and as a result of this investigation, we believe that Burnettizing is the advisable process to use for ties at present in this country. This, if well done (and it is nearly useless to do it otherwise), will cost 20 to 25 cents per tie, and a discussion of the economical results to be expected therefrom will be found in Appendix No. 17.

"Good results may be accomplished with sulphate of copper, but not only does this salt render wood brittle (more so, it is believed, than chloride of zinc), but as the copper attacks iron vessels, its use necessitates preserving cylinders of copper, and requires an expensive plant.

"The great defect of all mineral salts is that they are easily soluble in water, and so wash out in time, and leave the timber unprotected. Hence the many attempts to patent some method of retaining them in the wood. What these may be worth must be determined by time, but the desirable combination for this country would seem to be the impregnation of the inside of the tie with some metallic salt to poison the germs of decay, and a thin coat of creosote outside to repel the intrusion of moisture.

"If the timber is to be exposed in a comparatively dry situation, as in bridges, a trestle, or a fence, the results of this investigation indicate that Kyanizing is a good process to use. It does not seem to impair the strength of the timber as much as Burnettizing, and the latter accordingly is not recommended for those parts of structures (chords, ties, etc.) which are to bear tensile strains.

"Kyanizing costs about $6 per 1,000 feet, b. m., and success with it cannot be expected unless the work be well done. Caution will need to be observed in carrying it on, as corrosive sublimate is a violent poison.

"*Conditions of success.*—Your committee will therefore attempt to state the principal conditions to be observed to achieve success, so far as they have been disclosed by this investigation.

"(1) Select the appropriate process, in view of the subsequent intended exposure of the timber.

"(2) Select the more open-grained, porous, and sappy varieties of wood to operate upon.

"Antiseptics penetrate but little into the dense structure of White Oak, Burr Oak, and Yellow or Heart Pine, and are of doubtful utility for White Pine, Chestnut, or Spruce, while they readily impregnate and preserve the following varieties of wood: Hemlock, Sweet Gum, Mountain Pine, Loblolly Pine, Black Oak, Red Oak, Gray Oak, Water Oak, Beech, Poplar, Ash, Sour Oak, Cottonwood, Maple.

"The cheap woods, on the contrary, can be made to outlast the best woods in their natural state by a thorough artificial preparation.

"For railroad ties it will be advisable to select the harder kinds of wood to guard them against cutting into by the rails, especially upon curves. Preservation, however, materially adds to the natural hardness of timber, and it is found to resist cutting by the rail, under ordinary traffic, from 12 to 16 years.

"(4) Extract the sap and water, as far as practicable, before injecting the preservative. It is obvious that a liquid solution cannot be forced in unless there is a place for it, and yet most of the failures of valuable methods can be traced to neglect of this obvious requirement. Timber must be well seasoned either naturally or artificially before the antiseptic is injected, except in the case of the Boucherie process, which can only be applied to freshly cut logs.

"The Europeans operate, as has been stated, upon timber which has been cut and seasoned six months or more, and hence they find little trouble in injecting the solutions. In this country we must operate chiefly upon green or freshly cut timber, and hence must resort to steaming, if we use the pressure method of injection. Very good results are acomplished by steaming, but the work must be well done, and at such heat and pressure as not to injure the fiber.

"(5) Put in enough of the antiseptic to accomplish the desired result, and make sure that its quality and strength are such as neither to injure the fiber of the wood nor to leave it unprotected.

"(6) After the wood is prepared allow it to dry as much as practicable before using. Its durability will be materially increased by getting rid of surplus moisture.

"(7) Let there be no undue haste in carrying on the work. This is sure to result in unsatisfactory preparation.

"(8) In laying prepared ties or timber in the track protect them from moisture or water, as far as practicable, by draining the road-bed.

"(9) Contract with none but reliable parties. As an inspection subsequent to the doing of the work, short of chemical analysis, does not establish the fact whether it has been well done, and the results cannot be detected for some years, there will always be a great temptation to do bad or careless work under contracts. The safe course, therefore, for those who decide to have timber preserved is either:

"(*a*) To do the work themselves, under the supervision of experts;

"(*b*) To contract it at a sufficient price to honest and skillful parties, keeping an inspector at the works to note the daily working when the magnitude of the order will warrant it; or,

"(*c*) Contract the work on such terms that the profits shall depend upon the results accomplished in preserving the wood against decay.

"*Will it pay?*—The question as to whether it will pay to preserve timber against decay seems to have been answered very positively in the affirmative in Europe. There seems to be, indeed, no longer any question there about it; preservation is looked upon as quite a matter of course, and public works which fail to avail of it are alluded to as neglecting an important economy.

"In this country, preservation of wood (except in an experimental way) has been the rare exception, but the time has probably arrived when, in many sections, an economy of 20 to 50 per cent. a year can be obtained in the maintenance of timber structures and cross-ties by preparing them artificially to resist decay, while in other sections timber is still too cheap to warrant spending money to preserve it.

"This depends upon the price. Thus, where a White Oak tie costs 25 cents and lasts eight years, if we spend 25 cents in preparing it so that it will last sixteen years, we but double the life as well as the cost, and save only the expense of taking the old tie out and placing the new tie in the track at the end of the first eight years, if the price of the ties in the meanwhile continues the same.

"If, however, the Oak tie costs 75 cents, and we can substitute a Hemlock tie, which unprepared would last three and a half years, and cost 30 cents, and by preparing it extend its life to twelve years, at an additional cost of 25 cents, or even more, we then have a notable economy, both in first cost and in duration.

"In the case of piles, which are cut off by the *Teredo* in one or two years, as occurs in our southern harbors, the case is plain. They must be creosoted, or great waste and increased expense will result. In cases where they last eight to ten years, as in some northern sections, it will depend partly upon the value of the structure which the piles sustain whether it will pay to creosote them or not.

"In the case of bridges and trestles, much will depend upon the exposure, and the cost of maintenance, as well as upon the proximate exhaustion of suitable timber in the vicinity, and upon contemplated permanent renewals; while in the case of buildings, platforms, floors, &c., the ordinary wear from traffic will also have to be taken into account.

"The most important factor will be the exposure (wet or dry) and consequent rate of decay. Thus all brewers find it very economical to preserve their floors; and mills, bleacheries, dye-houses, &c., largely resort to artificial preparation of timber because of their exposure to slopping of water, and consequent moisture in heated apartments.

"The engineers and managers of the several works, therefore, will have to figure up for themselves, in view of the local circumstances of their case and the present and prospective price of timber, whether the economy of artificial treatment is sufficiently attractive to induce them to resort to it.

"The great consumers of timber are the railroads, and the managers of such enterprises have to be governed by a good many considerations, both of finance and of expediency, besides those of eventual economy.

"Hitherto, aside from the past cheapness of timber, the principal objections to its preparation against decay have been the lack of information as to what results could be confidently expected, and the conflicting claims of the promoters of various modes of treatment, each of whom represented his process as absolutely the best under all circumstances.

"Railroad managers naturally want to obtain immediate returns. They do not like to burden the revenues of the current year for the benefit of future administrations, and they are with reason jealous of every dollar that goes out now, even if it promises to save $2 or $3 in the future; yet, now that close competition requires every possible economy to be availed of, that railroads must more largely depend upon saving money in their maintenance, in order to continue or to resume their dividends, and that companies in good standing can obtain new capital for expense-saving appliances at 4½ or 5 per cent. a year, the time has probably arrived, in view of advancing prices and scarcity of timber, when some leading railroads will take steps to preserve it.

"Privy Councillor Funk estimates that in 1878, out of sixty millions of sleepers on the German railroads, twenty-five millions were impregnated, and that even with the extraordinary length of life stated for unprepared ties (13.6 years for Oak and 6.1 for Fir and Pine), had the remaining thirty-five millions of ties been impregnated there would have been a resulting economy of about $1,000,000 a year, or some 33 per cent. on the cost of renewals.

"This estimate is understood as having resulted in a material extension of tie-preserving in Germany, notwithstanding the fact that metallic ties have already been largely introduced in that country.

"As regards the latter, a simple calculation shows that the time has not yet arrived when they can profitably be introduced in this country. They will cost, laid in the track, about $2.50 each, and were they to last forever (the estimated life in Germany is twenty to forty years) the interest on the cost, at 5 per cent., would be 12½ cents a year a tie, or more than the annual charge of an unprepared White Oak tie, costing 77 cents in the track, and lasting seven years.

Record of Successful American Experiments in Wood-preservation.

No.	Locality.	Year.	Process.	Material treated.	Subsequent exposure.	Results.	Authority.
1	Vermont Central Railroad	1856	Bethell	Hemlock ties	Railroad track	Success, 1882	J. W. Hobart.
2	Chicago, Rock Island and Pacific Railroad	1860	do	Timber	Howe truss	do	Hugh Riddle.
3	do	1866	do	Ties	Railroad track	Success	M. Alexander.
4	Lehigh and Susquehanna Railroad	1867	do	do	do	Success, 1882	L. L. Buck.
5	New Orleans	1872	Boiling	Paving-blocks	Paving	do	T. Forstall.
6	East River bridge	1872	Steaming	Plank	Caisson	do	F. Collingwood.
7	Boston	1872	do	do	Floor	do	Blake Manufacturing Company.
8	Galveston	1874	do	Pine blocks	Stable	do	W. E. Gregory.
9	New Orleans and Mobile Railroad	1876	do	Piles	Teredo	do	J. W. Putnam.
10	Bound Brook Railroad	1876	Hayford	Ties	Railroad track	do	E. R. Andrews.
11	New Orleans and Mobile Railroad	1876	Steaming	Timber	Bridges	do	J. W. Putnam.
12	Delaware Bay	1878	do	Pine blocks	Teredo	do	W. Ludlow.
13	Philadelphia and Reading Railroad	1878	do	Ties	Railroad track	do	W. Lorenz.
14	Charlestown, Mass	1879	Thilmany	Spruce plank	Sidewalk	Success to 1882	S. G. White.
15	Hudson River Railroad	1869	Hamar	Ties	Railroad track	do	E. W. Vanderbilt.
16	Alexandria	1840	Steeping	Timber	Bridge	Success to 1862	W. R. Hutton.
17	Lowell Canal Company	1848	do	do	Bridges	Continued success	J. B. Francis.
18	Philadelphia and Reading Railroad	1850	do	Pine timber	do	do	J. D. Steele.
19	Blackstone Bridge	1854	do	do	Bridge	do	W. H. White.
20	Saint Louis, Mo	1879	Burnettizing	Gum blocks	Pavement	do	H. Constable.

REPORT ON WOOD-CREOSOTE OIL.

By William H. Bixby,
Captain of Engineers, U. S. A.;
Member of the American, British, and French Societies of Engineers;
Member of the American and British A. A. S.

The Southern Pine (*Pinus palustris*, Linn.) has already made a brilliant record for itself in the past through its valuable products in the shape of turpentine, pitch, tar, and rosin; but there remains for it a much more brilliant career in the future through its newer products wood-creosote oil and pine-leaf fiber, the oil being used mainly for preserving lumber, and the fiber for the manufacture of pillows, mattresses, and carpet matting.

The wood-creosote oil industry is at present carried on in the South mainly by the Carolina Oil and Creosoting Company, and Creosote-Lumber and Construction Company, of Wilmington, N. C., and the following description of the products and processes is based upon the practice of the latter manufactory.

Creosote is a general name applied to the oil products obtained by the destructive distillation of wood, coal, and other carbonaceous fuels after the temperature has risen above 200° or 300° F. If obtained by the distillation of coal, or coal-tar, this creosote is termed "dead oil," or coal-tar creosote-oil; if obtained from the distillation of wood, or wood-tar, it is termed wood-creosote oil.

Heavy resined, "fatty pine" wood, subjected to a heat of from 200° to 760° F., within closed iron cylinders, yields by distillation and condensation: (1) a wood-gas; (2) a small amount of wood naphtha; (3) a large amount of pyroligneous acid; (4) a large amount of wood-creosote oil; (5) a small amount of wood bitumen; and (6) a large amount of charcoal. Nine cords of good wood will yield a few gallons of naphtha and bitumen, 14 barrels of oil, 10 barrels of acid, and 168 barrels of charcoal.

The wood-creosote oil produced by this process is a dark, brownish, black oil, slightly heavier than water (3° to 4° Baumé), with a strong creosote odor, and possessing valuable antiseptic properties. Upon analysis it is found to contain about 5 per cent. of tar acids, about 15 per cent. of lighter oils, and 80 per cent. of heavy oils, which are insoluble in ether, fresh, brackish, or salt-water. This oil is an efficient poison to minute animal and vegetable life, and possesses an odor apparently intensely disagreeable to such life; it thoroughly repels moisture, and its tar-acids possess the power of coagulating albuminous and other fermentable matter. When properly prepared for such use it has been found to be an excellent insecticide to be employed on trees and smaller plants, especially for the destruction of larvæ attacking rose bushes, as also for destroying vermin on animals, in the cracks of floors, and in wooden buildings, and one of the best possible oils for preserving lumber and piling.

Experience in England* and in the United States† is unanimous in agreeing that creosoting is the only reliable method, so far tried, for preserving timber when exposed to salt water (and the *Teredo* worm), or to alternations of wetting and drying by either fresh or salt water. This experience also shows that the preservation of the timber is due mainly to those creosote oils which require over 400° F. for their volatilization, and that the pure creosote (with less tar-acids and with less light-oils) gives the best results.

Wood-creosote oil is much less expensive, and in many ways much more valuable, than the ordinary dead oil or coal-tar creosote oil heretofore used for such purposes as the preservation of timber. Wood-creosote oil contains all the acids needed to properly coagulate the albumen and sap which may be left in the timber, and to thoroughly destroy and prevent all further animal and vegetable life; it is of such nature that it will penetrate the wood both deeply and thoroughly; it contains a large proportion of insoluble matter, and especially of those oils which volatilize only under a heat of over 400° F.; and being derived from wood, it is especially adapted to use with wood.

In all these particulars, as well as in its less cost,‡ the resinous wood-creosote-oil is superior to the bituminous coal-tar creosote-oil (or dead oil), and, dollar for dollar, it will give far superior results in the preservation of timber from destruction and decay.

Applied with an ordinary brush to wooden or metal surfaces of all kinds, two coats of this oil (with an interval of two months between the applications) will effectually preserve these surfaces from wet and dry-rot, from rust, and from the attacks of worms and insects. Forced into the wood by hydraulic pressure, this oil will fill all the pores of the wood and extend its coagulating and antiseptic effects entirely through the wood to its very center. The good results obtained by the use of this wood-creosote oil have been thoroughly tested by the experience of five years in Mr. Mark's ship-yard, at Charleston, S. C., and at Mr. W. H. Northrop's bath-house, at Greenville Sound, near Wilmington, N. C., both places being such that untreated wood is badly damaged in a single season by rot and by the ravages of the *Teredo.* A log treated with this oil, and driven into salt-water, at Key West, Fla , in October, 1885, by the United States engineers, in February, 1887, was found to be untouched by the *Teredo*, although untreated logs were attacked by it in six weeks after they were driven. Similar results were obtained at about the same time by the United States engineers at Charleston, S. C., and at Pensacola, Fla.

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* See Proceedings of Institution of Civil Engineers for 1885.

† See Proceedings of American Society of Civil Engineers for 1885.

‡ It is to be regretted that the cost of treating wood with this wood-creosote oil has not been given, so as to admit of a comparison on a financial basis with the processes outlined by Colonel Flad. An effort to obtain the same has so far proved unsuccessful.—B. E. F.

The comparative invulnerabilty to fire possessed by wood that has been treated with this oil has been proved at the burning, in the fall of 1886, of the Atlantic and North Carolina Railroad wharf, at Morehead City, N. C., where the creosoted fender-piles remained almost without damage by the fire, while the wharf and shed next to them were burned down entirely. Live coals and ordinary flames are unable to kindle any fire in wood impregnated with this wood-creosote oil.

The pyroligneous acid produced during or just before the distillation of the wood-creosote oil is a light-colored, vinegar-like liquid, slightly heavier (4° to 7° Baumé) than water, and also slightly heavier than the wood-creosote oil. This pyroligneous acid, in its crude and undiluted state, is an excellent and inexpensive disinfectant, immediately arresting putrefaction and preventing any further development of the disagreeable and unhealthy odors arising therefrom. It is equally if not more efficacious than carbolic acid, as well as being free from odor, which makes that acid so disagreeable (at least to many), and it is nearly or quite as efficacious as corrosive sublimate, and is free from the poisonous qualities of this chemical. It is an excellent remedy for skin diseases in animals; makes good vinegar and alcohol, and is said to preserve meats for an indefinite time. As a disinfectant it has been used in large quantities and with great success in the streets, stables, privies, etc., of Wilmington, N. C., under direction of the city authorities.

The charcoal produced by this process is one of fine quality and of remarkably even texture, well adapted for use in the smelting of iron, as well as for ordinary fuel. When finely pulverized (as at the Wilmington works) it can be advantageously used in the place of lamp-black in the manufacture of paints for the preservation of wood, as also for the preservation and insolation of metals.

As will be seen from the above the most important product of the distillation of pine wood is the wood-creosote oil, and the most important use (commercially) of this oil is as a preservative of timber and lumber.

The general features of the process of distillation and subsequent use of this oil are as follows:

Ordinary "light wood" (or "fatty pine" wood) is cut up into sticks of about 4 feet in length, and about five cords of these sticks closely packed inside of a large cylindrical iron retort. The doors of this retort are then closed and hermetically sealed. A fire is then built in the furnace under the retort, and the heat and flames are directed as uniformly as possible all around the outside of the retort. As the temperature inside the retort increases from 100° to 700° F., the liquid and some of the solid portions of the wood are converted into gas and vapor, and pass out of the retort through a copper "worm" inclosed in a cold-water tank and are collected in the form of wood-gas, naptha, acid, and oil. When the oil ceases to run, the fires under the retort are put out, the bitumen is drawn off through a tube coming from the bottom of the retort, and the latter is then allowed to cool off. As soon as possible, therefore, the doors of the retort are opened and the charcoal raked out. The operation is thus finished, and the retorts are ready for a fresh charge.

Timber and lumber which is to be treated with this oil must be first prepared to receive it. Timber is taken directly from the river by large derricks, is landed on the wharf, is stripped of its bark, and then exposed to the sun for a week or ten days to dry. At the end of this time it is placed (one stick at a time) on trucks, is rolled into the carbonizing cylinder, is there exposed from about ten to twenty minutes to an intense radiated heat, and is then withdrawn charred to a depth of one-fourth of an inch, thoroughly dried to a depth of three-fourths of an inch, and thoroughly heated to a depth of several inches.

The carbonizing cylinder consists of a wrought-iron cylindrical tube about 21 feet long by 28 inches in diameter, set in a brick furnace, fired at the side and midway of its length, the cylinder being brought to a proper and uniform heat by means of a wood fire, the heat and flames of which pass by vertical and horizontal flues along and all around the cylinder. The cylinder is further provided with a small railroad track and iron carriage on the inside, for the convenient handling of the timber. Sawn lumber is not usually charred, but is sometimes kiln-dried or semi-charred; the objection to the charring being that it destroys the sharp edges of the lumber. The charring or carbonizing of the process, therefore, consists in taking the timber and subjecting it to a dry radiant heat within the suitable cylindrical surfaces in such manner as to drive out of the timber most of its sap and albuminous matter (ordinarily about five pounds to the square foot), drying the inside of the timber, charring its outside, and leaving the wood with its pores open and in condition to be completely filled with the wood-creosote oil thereafter applied to it.

Charred timber, once thoroughly carbonized, will not crack under subsequent exposure to the sun and air. If further properly treated with wood-creosote oil, it will withstand all attacks of atmosphere, moisture, and animal life, and will last for years anywhere.

This process for carbonizing and creosoting timber is such that it does not injure the fiber of the interior of the wood. It is one of the simplest, cheapest, quickest, most effective, and most successful processes so far known for artificially seasoning and preserving wet or green timber, in cases where the want of time or money do not allow a thorough natural seasoning of at least six months' exposure to the atmosphere. Although other and improperly applied methods of dry-heating and after-creosoting may render timber brittle under the pile-driver, none of the timber so far carbonized and wood-creosoted has proved objectionable from this cause. On the contary, the wood-creosote restores the toughness and elasticity to the charred wood, so that this method has given great satisfaction wherever used, as, for example, at Aspinwall, Panama, under the Panama Canal Company; and at Charleston, S. C., under the Northeastern Railroad Company; in both cases under circumstances extremely unfavorable to the life of the timber.

After the wood has been carbonized or kiln-dried, it is loaded upon trucks, which, with their load, are rolled into the creosoting cylinders, respectively of 65, 75, and 90 feet in length, each with a diameter of 6 feet. The doors of the creosoting cylinder are then closed for from four to fifteen hours, during which time the temperature within the cylinder is raised by dry heat to from 140° to 160° Fr., a vacuum of from 9 to 24 inches is kept up by means of a vacuum-pump, and the sap, albumen, and other impurities are thus thoroughly extracted from the wood and pumped out of the cylinder.

The vacuum-pump is then stopped and a force-pump put to work, by which the cylinder is filled with hot wood-creosote oil, under a pressure of from 65 to 100 pounds per square inch, this pressure being constant from four to eight hours, according to circumstances. By this part of the process from eight to twenty pounds of oil are forced into each cubic foot of wood. The pressure is then relaxed; the unabsorbed oil is then run off into outside tanks, the doors of the cylinders opened, and the impregnated timber, still on its trucks, is rolled out.

This treatment with wood-creosote oil, as above described, has been favorably reported upon (March 18, 1886) by a special board of United States Navy officers; and the wood so treated has had an extensive use already upon the Government wharf at Charleston, S. C., at the jetties at Port Eads in the M. T. and E. P. Inclined Railway at Cincinnati, Ohio, as well as in many other less important places and structures.

Treatment with this oil is especially valuable to wood that is to be used in the construction of bath-houses, wharves, docks, quays, piers, railroad bridges, railroad trestles, wooden pavements, flats, lighters, scows, ship spars and masts, ship decks and bottoms, or used in railroad cross-ties, foundation sills for houses, piazzas, porches, floors, fence-posts, and telegraph poles. No cases have yet been discovered where either rot or *Teredo* has attacked wood that was thoroughly impregnated with this wood-creosote oil.

ADDENDA.

By B. E. F.

In the experiments recently made by Dr. Boehme, to ascertain the relative effect on impregnated and natural wood, samples of various treatment demonstrated that impregnated wood absorbed much less water than the natural wood. Increase in volume in consequence of absorption of water was less in the impregnated than in the natural samples.

Tests of the bending strength of the samples showed that those impregnated were stronger by 15 per cent. Resistance to compression was greater by about 22 per cent. in the case of the impregnated samples.

It would appear of interest to state here that by creosoting the strength of the timber is also increased. The following results confirming this view are taken from some experiments which were submitted to the British Civil and Mechanical Engineers' Society some time ago. The sizes of the pieces tested were 2 feet 6 inches by 2 inches by 1½ inches; the pressure was applied midway between supports 2 feet apart.

Series No. 1.—Six pieces of Memel fir, not creosoted, weighing 9¼ pounds.		Series No. 2.—Six pieces of Memel fir, creosoted, cut out of the same plank as preceding, weighing 13½ pounds.		Series No. 3.—Six pieces of Scotch fir, not creosoted, weighing 9 pounds.		Series No. 4.—Six pieces of Scotch fir, creosoted, cut out of the same sleeper as the preceding, weighing 16½ pounds.	
	Cwt.		*Cwt.*		*Cwt.*		*Cwt.*
No. 1 broke with	12½	No. 1 broke with	12	No. 1 broke with	15	No. 1 broke with	16
2	10½	2	12	2	14	2	14
3	10½	3	11	3	12½	3	14½
4	11½	4	11	4	13	4	17½
5	11	5	11½	5	13½	5	14
6	10	6	12½	6	14	6	16
Average....	11	Average....	11⅔	Average ...	13⅔	Average....	15⅓

Summary of Average Results.

	Cwt.
Memel fir not creosoted	11
Memel fir creosoted	11⅔
Scotch fir not creosoted	13⅔
Scotch fir creosoted	15⅓

CARBOLINEUM AS A PROTECTION AGAINST THE DECAY OF WOOD.

According to F. Engel, Government surveyor of buildings, painting wood with carbolineum as a protection against the weather and rot gives favorable results. The Imperial Government surveyor of buildings also confirms this statement in a certificate under date of January 19, 1885, in which he states that on the imperial roads wood-work used in underground construction during the years from 1870 to 1885, when painted with carbolineum, had no decay up to date of certificate.

For the sake of experiment, two pieces of pine wood, taken from the same plank, were thus treated: The first was painted with carbolineum, while the second was left in its natural state, and both placed in the ground under the same conditions. At the end of three years the painted specimen was found to exhibit no signs of decay, but the unpainted one was in a rotten state.

The district surveyor of buildings inclines very favorably to the use of carbolineum on buildings in the water, and on sluice-gates, dam-barriers, piles, posts, especially when the wood is kept wet or dry, or by turns wet and dry.

It is found that carbolineum is cheaper than the semi-fluid tar. For an area of six square meters one kilogram of carbolineum is ordinarily used; and its superiority over tar is shown by the fact that even the largest manufacturers, where tar is a by-product, and the use of which costs nothing, are coming to use carbolineum.

It is best and most advantageous to paint with hot carbolineum, for in this state it is more fluid than when unboiled, and for this reason penetrates into all cracks and openings, at the same time dissolving any resin or oil present; it also disinfects more energetically in a warm state than in a cold one. In warm weather, and on wood when the surface is not buried in the earth, it is necessary to give a thicker coating of the unheated oil, especially as it can be repeated after a while. Wood that is not completely air-dried must always be treated with hot carbolineum. All the wooden posts of bridges that are exposed to changes of wet and dry, as well as their gravel-covered layer of planks, are painted with two coats of hot carbolineum. All knotty wood surfaces must be very carefully treated, applying only so much as will be readily absorbed. The knotty surfaces of wood being the places where the ducts open, these are thus the very localities where the decay and destruction from lower organisms begin, and it is on this account that they must receive special protection. One kilogram of carbolineum (which comes in casks of about two hundred kilos. each), costs 0.3 marks=7 cents.

ANNUAL CHARGES FOR TIES.

By B. E. Fernow.

There appears to have been some difficulty experienced by engineers in coming to a conclusion as to how different processes ought to be compared in regard to the annual charge, which must vary according to the difference of the initial cost of the ties and the difference in the number of years that they will last, and, in addition, to the frequency at which the expense of renewal recurs. The difficulty, it seems, need not exist at all, and can be removed by the application of simple mathematical formulas and mathematical deductions, and put into a form which will allow a ready comparison of the annual charge for ties of different prices and varying conditions. For this purpose the following tables have been constructed, which give answer in a convenient manner to many questions that may be put in connection with the matter of charges.

From Table I. we find, for instance, if we pay 40 cents for a tie, the life of which is six years, making the annual charges 7.88 cents, that we can afford to pay 15 cents per tie in addition for a process that will lengthen its life to nine years; or, if we pay 25 cents for a preserving process, making the initial cost 65 cents, the life of the tie must be increased to at least eleven years in order that it may not increase the annual charge. Or if an oak tie, lasting eight years, can be bought for 50 cents, it would be cheaper to buy hemlock at 30 cents, though it may last but five years.

The formula used in the construction of Table I. is that for the capitalization of regular annual rents, and, by transposition, assumes the form, $r=\frac{R\ 1.0\ p^{n}}{1.0\ p^{n}-1}0.0\ p$, in which r=rent or annual charges; R=capitalized rent; p=rate of interest; ^{n}=the number of years for which the charge is to run; and $1.0\ p=\frac{100+p}{100}$. p is taken at 5 per centum, but as the table is intended only for purposes of comparison, the rate of interest is really irrelevant, except to allow a statement of the amount of saving or increased expenditure effected.

In this table no account is taken of the reduction in annual charges due to the less frequent expenditure for renewal with ties of longer duration. For this a separate calculation and addition are necessary, for which the figures are given in Table II.

For the expense of renewal occurring in stated but not at yearly intervals, the formula for the capitalization of intermittent rents is applicable, which by transposition appears as $r=\frac{R}{1.0\ p^{n}-1}0.0\ p$. For each cent of such expense, then, the amount which appears under the year at which renewal becomes necessary should be added to the annual charge found in Table I. Example: An oak tie costing 50 cents in the road-bed, and lasting eight years, would make an annual charge of 7.74 cents; the extra expense for renewal every eight years, at 10 cents per tie, would increase this annual charge by 0.105 × 10=1.05 cents, or total annual charge equal to 8.79 cents. The same tie, by creosoting, made to last sixteen years, in order to keep the annual charge the same, may cost 90 cents, for annual charge due to cost of renewal 0.042 × 10=0.42 cents. Charge on cost of 90 cents,

8.30 cents,

8.72 cents, the total annual charge.

TABLE I.—*For computing Annual Charges.*

Initial Cost.	Years of duration.																	
	5.	6.	7.	8.	9.	10.	11.	12.	13.	14.	16.	18.	20.	22.	24.	26.	28.	30.
	Cents.	*Cents.*	*Cents.*	*Cents.*	*Cents.*	*Cents.*	*Cents.*	*Cents.*	*Cents.*	*Cents.*	*Cents.*	*Cents.*	*Cents.*	*Cents.*	*Cents.*	*Cents.*	*Cents.*	*Cents.*
30 cents	6.93	5.91	5.18	4.64	4.22	3.89	3.61	3.38	3.19	3.03	2.76	2.56	2.40	2.27	2.17	2.08	2.01	1.95
35 cents	8.08	6.89	6.04	5.41	4.92	4.53	4.21	3.93	3.72	3.53	3.22	2.99	2.80	2.65	2.53	2.43	2.34	2.27
40 cents	9.23	7.88	6.90	6.19	5.62	5.18	4.81	4.49	4.25	4.04	3.69	3.42	3.20	3.03	2.89	2.78	2.68	2.60
45 cents	10.30	8.86	7.76	6.96	6.32	5.82	5.41	5.04	4.78	4.54	4.15	3.84	3.61	3.41	3.26	3.12	3.01	2.92
50 cents	11.54	9.85	8.63	7.74	7.03	6.47	6.01	5.60	5.32	5.05	4.61	4.27	4.01	3.79	3.62	3.47	3.34	3.25
55 cents	12.70	10.84	9.49	8.51	7.73	7.12	6.61	6.15	5.85	5.55	5.07	4.70	4.41	4.17	3.98	3.82	3.68	3.57
60 cents	13.85	11.82	10.35	9.28	8.43	7.72	7.21	6.71	6.38	6.06	5.53	5.12	4.81	4.55	4.34	4.16	4.01	3.90
65 cents	15.00	12.81	11.22	10.06	9.14	8.41	7.81	7.26	6.91	6.56	5.99	5.55	5.21	4.93	4.70	4.51	4.35	4.22
70 cents	16.16	13.79	12.08	10.83	9.84	9.06	8.41	7.82	7.44	7.07	6.45	5.98	5.61	5.31	5.07	4.86	4.68	4.55
75 cents	17.31	14.78	12.94	11.61	10.54	9.71	9.01	8.37	7.98	7.57	6.91	6.41	6.01	5.69	5.43	5.21	5.02	4.87
80 cents	18.47	15.76	13.81	12.38	11.25	10.36	9.62	8.93	8.51	8.08	7.37	6.83	6.41	6.06	5.79	5.55	5.35	5.20
85 cents	19.62	16.75	14.67	13.15	11.95	11.00	10.22	9.48	9.04	8.58	7.83	7.26	6.81	6.44	6.15	5.90	5.69	5.12
90 cents	20.97	17.73	15.53	13.93	12.65	11.65	10.82	10.04	9.57	9.09	8.30	7.69	7.21	6.82	6.51	6.25	6.02	5.85
95 cents	21.93	18.72	16.39	14.70	13.35	12.30	11.42	10.59	10.10	9.59	8.76	8.12	7.62	7.20	6.89	6.50	6.36	6.17
100 cents	23.08	19.70	17.26	15.48	14.06	12.95	12.02	11.15	10.64	10.10	9.22	8.54	8.02	7.58	7.25	6.94	6.69	6.50
105 cents	24.24	20.69	18.12	16.25	14.76	13.59	12.62	11.70	11.17	10.60	9.68	8.97	8.42	7.96	7.61	7.29	7.03	6.82
110 cents	25.30	21.67	18.98	17.02	15.46	14.24	13.22	12.26	11.70	11.11	10.14	9.40	8.82	8.34	7.97	7.63	7.36	7.15
115 cents	26.54	22.66	19.85	17.80	16.17	14.89	13.82	12.81	12.23	11.61	10.60	9.82	9.22	8.72	8.38	7.98	7.70	7.47
120 cents	27.70	23.64	20.71	18.57	16.87	15.53	14.42	13.37	12.76	12.12	11.06	10.25	9.62	9.10	8.70	8.33	8.03	7.80
125 cents	28.85	24.63	21.57	19.35	17.57	16.18	15.02	13.92	13.30	12.62	11.52	10.68	10.02	9.48	9.06	8.68	8.37	8.12
Add for each additional 5 cents	1.154	0.985	0.863	0.774	0.703	0.647	0.601	0.560	0.532	0.505	0.461	0.427	0.401	0.379	0.362	0.347	0.334	0.325

TABLE II.—*For computing Annual Charge of Renewal.*

Cost of Renewal.	Year of Renewal.																	
	3.	4.	5.	6.	7.	8.	9.	10.	11.	12.	14.	16.	18.	20.	22.	24.	26.	28.	30.
	Cents.	*Cents.*	*Cents.*	*Cents.*	*Cents.*	*Cents.*	*Cents.*	*Cents.*	*Cents.*	*Cents.*	*Cents.*	*Cents.*	*Cents.*	*Cents.*	*Cents.*	*Cents.*	*Cents.*	*Cents.*	*Cents.*
1 cent	0.317	0.232	0.181	0.147	0.123	0.105	0.09	0.079	0.07	0.063	0.051	0.042	0.039	0.03	0.026	0.023	0.019	0.017	0.015
10 cents	3.17	2.32	1.81	1.47	1.23	1.05	0.90	0.79	0.70	0.63	0.51	0.42	0.39	0.30	0.26	0.23	0.19	0.17	0.15
12 cents	3.80	2.78	2.17	1.76	1.48	1.26	1.08	0.95	0.84	0.76	0.61	0.50	0.47	0.36	0.312	0.28	0.23	0.20	0.18
15 cents	4.76	3.48	2.72	2.21	1.85	1.58	1.35	1.19	1.05	0.95	0.77	0.63	0.59	0.45	0.39	0.35	0.29	0.26	0.235
20 cents	6.34	4.64	3.62	2.94	2.26	2.10	1.80	1.58	1.40	1.26	1.02	0.84	0.78	0.60	0.52	0.46	0.38	0.34	0.30

Appendix No. 3.

METAL RAILROAD TIES.

By B. E. FERNOW.

The following notes on the subject of metal ties were gathered from numbers of leading technical journals (largely foreign and therefore less accessible), and represent opinions and experiences of competent railroad engineers, also what little experience and information could be gathered from American practice. If, therefore, statements on some points seem not to harmonize, it must be inferred that opinions of good authorities differ as to those points. Hardly more than the arrangement of matter is claimed to be original. The object of this compilation is to present in a ready form for reference the scattered data, and to aid the railroad managers in forming their opinion as to the advisability of employing the substitute for wooden ties on their own roads.*

In the foregoing report, to which these notes form an appendix, it has been shown that the railroads of this country consume yearly about 75,000,000 wooden ties, having an estimated actual cost value of at least $25,000,000.

This consumption forms no inconsiderable drain upon the forests of the country, and the need of economy in the use of these resources should secure a ready welcome to any substitute for wooden ties, at least in an experimental way. Mr. C. P. Sandberg, the well-known expert in railroad matters, says: "The enormous consumption of wooden ties and their rapid decay, particularly in hot countries, make the use of metal ties desirable, especially with the decreasing price of metal and the greater expense of wooden ties. The substitution of metal ties for wooden ones is of course entirely a question of locality and of price."

Although the impregnation of ties does somewhat retard the process of decay, yet the use of wood for railroad purposes cannot be considered satisfactory.

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* The journals consulted are mainly Schweizerische Bauzeitung, Organ für Fortschritte des Eisenbahnwesens, Revue Générale des Chemins de fer, Glaser's Annalen fur Gewerbe und Bauwesen, Congrès des Chemins de fer à Bruxelles, compte rendu générale, 1886.

Changing conditions of weather, by repeated soaking and drying of the tie, inevitably induce change of volume, and therefore alone make a safe fastening of the rails to a wooden tie problematic.

To this add the also problematic capacity of the fastenings, whether spikes or bolts, to secure the rail.

Further, there is to be considered the very unequal capacity of resistance which ties show, according not only to the kind of timber, but to the locality from which they come. This difference of quality depends on a number of influences, such as the conditions of the soil on which the tree has grown, the age of the tree, as well as the season of its felling, and cannot be overcome by impregnation or otherwise.

Quite different are the possibilities in this respect with iron or steel as material.

The unevenness of the track, produced by varied behavior of the ties, works detrimentally also on the rails and on all parts of the roadbed, so that for safety as well as efficiency and ultimate economy alone the metal superstructure deserves consideration.

From a railway point of view the introduction of metal ties recommends itself as affording additional revenue, if otherwise the cost of first construction and of maintenance is satisfactory, *for the manufacture of a ton of steel ties creates a traffic over the railways of two tons of raw material.*

The first introduction of metal (then iron) ties dates back probably to the year 1864, when the Brunswick railways in Germany laid test lengths of longitudinal iron stringers, so that an experience of over twenty years, valuable on some points at least, is afforded. The Dutch and Swiss companies followed soon with improvements in the system of construction, and the use of this substitute has been gradually extended, so that now all the railroad companies of Holland have introduced metal ties on their lines.

In order to make the first introduction of metal ties possible, it was necessary to make the initial cost of the longitudinal tie (Hilf system) as near that of the wooden structure as possible; consequently they were rolled unduly thin, the rail also was made weak, and thus breakages were not unfrequent, creating distrust of the system. The attempt to remedy this by increasing the weight of ties from seventy-seven to one hundred and sixty-five pounds failed on account of the increased expense. The same fate attended the attempt to strengthen the tie by riveting or bolting to it plates for the rail to rest on, because of increased cost and less secure connection between rail and tie.

Two systems of metal superstructure have been used in practice, the longitudinal and the cross-tie.

The first metal ties were constructed upon the longitudinal system (Hartwich, Hilf, Scheffler), and even to-day, after nearly a quarter of a century of trial, opinions as to the superiority of one or the other system are wide apart, though latterly preference seems to favor the cross-tie plan. The longitudinal ties, which were at first thought to be the only possible form, are abandoned gradually for cross-ties. Statistics as to the use of metal cross-ties on the Continent in 1885 were given before the Railroad Congress at Brussels as follows:

	Companies.	Miles laid with metal.	Total length of roads.
Germany	9	1,806	14,754
Holland	4	181	2,053
Switzerland	4	49	1,530
	17	*2,036	18,337

* 11 per cent.

One of the Swiss companies—the North Eastern Railway of Switzerland—has definitely adopted metal cross-ties for all new roads and the renewal of old ones.

In England the drain which the Indian railways made in the tie market induced experiments with steel ties in 1884. Twenty steel ties (Vautherin pattern), ninety pounds per tie, with rail of ninety-five pounds, bull-headed form, lying in two half chairs, were laid. Creosoted paper was placed underneath the ties to deaden the sound. To-day millions of metal ties are used in India.

The Mexican Railway (Vera Cruz), after an experiment of two years with twenty thousand steel ties on level ground and on heavy grades, has proposed to put in yearly hereafter from forty to fifty thousand.

The change from the wooden to the steel tie is made entirely in the interest of economy, and it is calculated that in a few years the permanent section-gang on the road can be replaced by traveling gangs, who will be able to keep the road in order, the number of men employed under the new system being only 50 per cent. of those embraced in the present permanent section system.

No better testimony to the efficiency of the metal tie under proper condition could be given than the following extracts from a letter in reply to a request for information from George Foot, Esq., Superintendent of the Mexican Railway, stating his experience.

"Our experience with these ties, of which some 30,000 have been in the line since September, 1884, is so satisfactory in every respect, that we are now about to lay down 40,000 more, and our intention is to gradually relay the entire line with metallic sleepers.

"I inclose a blue print*, showing the type of tie we are about to lay down, one which is about the same as that employed on the State railways of India for both the 5.6-meter gauges, but arranged for our gauge, which is 4′ 8½″.

"The price of the new ties under contract in England is 4*s.* 4*d.* ($1.05) each, including steel keys f. o. b. in Cardiff, and their weight with keys 112 lbs. each.

"The metallic ties in use here for the last two years are almost of the same pattern as shown on the drawing, excepting the fastenings, which are much more complicated and expensive.

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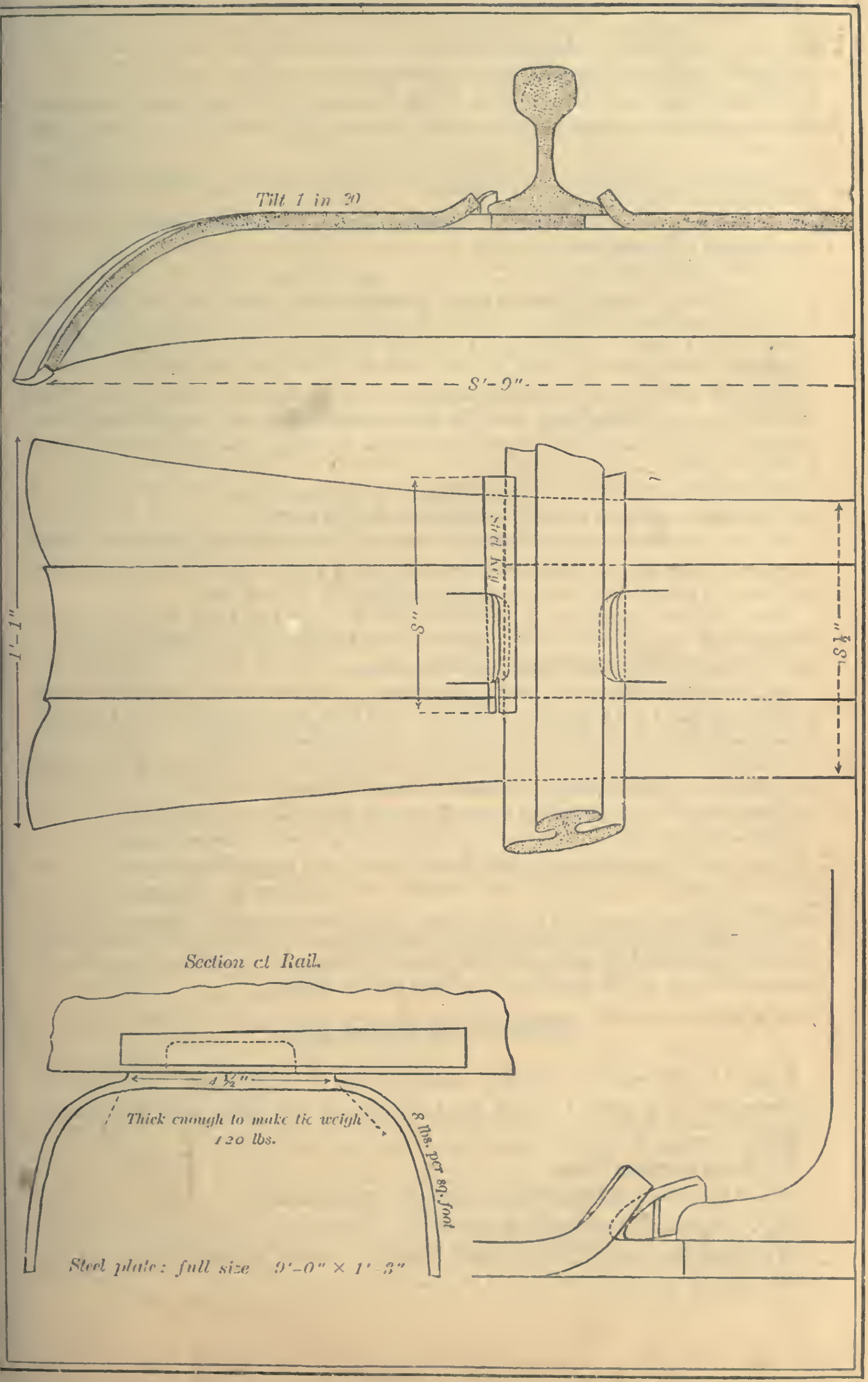
* See Plate No. I, p. III.

PLATE I.


Tilt 1 in 20
8'-9"
1'-1"
8"
Steel Key
8½"
Section at Rail.
4½"
Thick enough to make tie weigh 120 lbs.
8 lbs. per sq. foot
Steel plate: full size 9'-0" × 1'-3"

INDIAN STATE RAILWAYS.—STEEL TIE FOR 75-lb. RAIL

"The blue print which I inclose represents the latest improvements in steel sleepers suggested by experience on railways in India, where millions of them are employed, and I think that the tie in question leaves little to be desired either in general form, simplicity of fastenings, weight, or price.

"You will observe that the metal is thickened where strength is most required, and that the rail clips are formed from the solid plate, the rail being kept in place by a simple steel key which can be driven either on the inside or outside of the rail when increased width of gauge is required on sharp curves.

"You ask me to state the advantages and disadvantages experienced by us in the use of this class of sleeper.

"So far we have no disadvantages to record, but many and very important advantages, which are as follows:

"(1) No spikes are required.

"(2) The rails are kept to gauge with almost mathematical accuracy and the result is that the oscillation of a train running at high speed over this track is reduced to a minimum, and is very marked when it runs on to a length laid with ordinary timber sleepers.

"(3) The difference in the cost of maintenance is enormous, because a track once properly laid with these steel ties and well ballasted requires no permanent road gangs and can be maintained in good order by a traveling gang going over it once or twice a year.

"This is our experience here, but it must be remembered that on this railway we have no frost or snow to contend with and very light traffic.

"In the United States these conditions would of course be altered, but I see no good reason why these ties should not bear frost well; they are extensively used in Germany and I am not aware that frost has proved an objection to their use.

"From personal experience I cannot say how metallic ties behave in cases where trains run off the line, as we very seldom on this line have such accidents, and have had none on the portions of track laid with them.

"In India the experience is that in a bad run-off a great number of ties are bent and injured, but that very few are so badly damaged as to be past repairs, and that, as a general rule, they are repaired in the shops and replaced in the line.

"I must add, however, that metallic sleepers require a very solid and perfect road-bed, and a much larger quantity of ballast than timber ties.

"The Mexican Railway is laid throughout with 62-pound steel rails, except on the Cumber 4-per-cent. incline, where we are now laying down 82-pound rails.

"Our metal ties are laid under the 62-pound rails, the number being 2,000 per mile but we find that this number is not necessary, and in future we propose to lay only 1,850 per mile.

"I may say in conclusion, that in my opinion the steel tie is the tie of the future, and that our experience here points with their use to substantial economies in repairs and maintenance and at the same time to a very perfect track."

GENERAL REQUIREMENTS.

From the experience so far accumulated it is claimed that the requirements of a good tie can be fulfilled by the steel ties now made, namely:

(1) Appropriate form.

(2) A section with sufficient moment of resistance.

(3) A material not easily fractured.

(4) Sufficient bearing area and length to resist lateral, longitudinal, and vertical strains.

To which may be added that:

(1) The average life of good steel ties is considerably longer than that of best wooden ties (estimated at 30 to 50 years).*

(2) The width of gauge is better maintained with steel ties.

(3) Cost of maintenance of permanent road with steel ties remains almost constant after the second year, while with wooden ties it increases constantly with age, making the average cost greater than with the former.

(4) Rail fastenings are possible with steel ties which are at once safer and more easily maintained than those for wooden ties.

(5) A good steel tie should not cost more than from 125 to 150 per cent. of the cost of wooden ties.

(6) The "old material" value of a steel tie is greater than that of a wooden sleeper.

"If, for comparison of the relative cost per mile of steel and wood, account is taken of the manufacture, transport, laying, maintenance, interest, and value of scrap, it is seen that there are few countries in the world where the exclusive use of wood ties is really economical.

"For countries where climate and insects destroy wood sleepers in a few years this is evident; but it speaks still better for steel sleepers that in Holland, which produces no steel and gets wood sleepers very cheaply by sea, all the railway companies have introduced metal sleepers without any pressure from the Government."

REQUIREMENTS AND COMPARISON OF DIFFERENT SYSTEMS OF SUPERSTRUCTURE.

A very elaborate investigation into the merits of different systems of superstructure, with wooden and metallic longitudinal or cross-ties, has been published in the "Organ für Fortschritte des Eisenbahnwesens" for 1886, by a high authority, W. Fuchs, replete with mathematical demonstrations and presenting a most thorough discussion on theoretical grounds, the results of which are given in the following notes:

A.—*The aggressive forces against which any system of superstructure must be prepared to stand, are,—*

(*a*) Vertical: pressure at the wheel, usually and properly taken as 7,000 kilograms (15,400 pounds).

(*b*) Lateral: shocks representing a total effect of 5.5 tons, discounted by a relief of 2 tons from the opposite wheel, the total pressure being roughly 5,000 kilograms, which may increase to the maximum 8,000 kilograms (11,000 to 17,600 pounds).

(*c*) Longitudinal: per rail not over 5,025 kilograms, adhesive weight of locomotive taken as 42,000 kilograms.

B.—*Requirements of systems.*

(*a*) Longitudinal ties.

The manner, shape, and number of cross-connections seem to be of utmost importance; blade-shaped connections are preferable to those with broad surface on account of the tendency of the latter to form humps in the road-bed; a number of cross-connections is undesirable as counteracting the advantages of the long tie and introducing the faults of the cross-tie system; the connection is best made at the rail joint, by which the favorable influence of such connection is utilized. If more connections are required, they are best applied in the middle, at equal distances from the ends of the tie.

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* See p. 119, on Life of Metal Ties.

The main difficulty of long-tie systems lies in their deficient drainage, two "backs" forming alongside the tie in the road-bed. This objection is increased when the cross-connection has a flat surface.

Of all long-tie systems Haarmann's (employed on Berlin City Railway) appears best, exception being taken only to the form of cross-connection. Hilf's system is found in all points inferior, the former showing all the advantages required for an elegant and simply constructed superstructure; the only objection to it is that to which all long-tie systems are open—deficient drainage.

(*b*) Cross-ties.

The parts of the rail lying between the support and a point half way between supports receive less wear, and an uneven use of the rail is the consequence. Connections of rails to ties can never be made too rigid. The foot of the rail should preferably not be supported in its entire breadth, but only on its flanges to a sufficient breadth, thereby insuring more stability, permitting the use of rails not having a perfectly smooth foot, and avoiding an extra demand of resistance against tilting on the part of fastenings.

Bed-plates are most desirable for wooden as well as metal cross-ties, making the manufacture of the latter ties less expensive and less difficult.

By use of bed-plates the eating into parts most used, and the consequences resulting therefrom, on all parts of the superstructure, can be avoided. The best mode of fastening is presented by bed-plates with hook bolts.

The best length for metal cross-ties is given as 227.7 c. m. (7 feet 5½ inches); and in order to diminish the strain on the tie and counteract the tendency of every cross-tie system to change the gauge in consequence of a bending of the tie, there should be no tamping underneath for a length of 52.7 c. m. (20.7 inches). A trough, open only on the lower side, divided into three compartments by two cross-ribs placed 26.35 c. m. (10.3 inches) from the center of the tie, the outer parts filled with bed material, the central part empty, will answer to this requirement.

At 10 c. m. (3.93 inches, the height of a cross-tie), a metal cross-tie system furnishes, even in the most unfavorable bed material, at least 1.33 times greater resistance to side strains than a wood superstructure.

The distance of ties, at 1 m. (3.28 feet), used on the Prussian profile, the author considers too great, and 0.95 m. (3.12 feet), or even less on curves, just permissible. Against longitudinal forces the transmission of the shock from the rail to the tie is more imperfect with metal systems than with wooden ties; yet the resistance of a good metal system to displacement in the direction of the track is very much greater than with wooden ties. Iron ties of 10 c. m. (10.3 inches) height withstand the effects of longitudinal forces.

RESULTS IN REGARD TO METAL CROSS-TIES.

The cross-tie with short steps leaning somewhat outward is the most perfect.

The need of bed material is smaller than in any other superstructure.

Bed-plates with bolts offer very firm connections, and can be easily moved or replaced. Changes of gauge can be as easily and accurately effected as with other connections. The mode of fastening is independent of the form of tie, and can be applied to any iron tie at any later time.

The weight per running foot ought to be somewhat greater than that of ties now used, but the greater weight refers to such parts as are little subject to wear, and it does not exceed that required in the long-tie system.

C.—*Comparison of wood and metal superstructures.*

The superiority of well-devised metal superstructures over those with timber ties as usually applied, is more clear if we consider the more or less secure mode of fastenings in both systems.

If the greatest side strain of 7,350 kilograms (16,000 pounds) be exerted on the rail just over the tie, and if two spikes are used outside and one inside for fastening, then if the coefficient of friction between metal and wood be $u=\frac{1}{2}$, the two outside spikes must offer resistance $R=7{,}350-\frac{6000}{2}=4{,}350$ kilograms (9,570 pounds), while under usual conditions they cannot offer more than 3,200 kilograms (7,040 pounds); one shock, therefore, is capable of loosening the rail here. Only when the three spikes are united by bed-plates does their resistance grow to 4,800 kilograms (10,560 pounds), or their total combined resistance to $4{,}800+3{,}000=7{,}800$ kilograms (17,160 pounds), against a strain of 7,350 (16,000 pounds). But this resistance is found only in absolutely sound ties. Still less secure is the usual mode of fastening against tilting; for the inside spike cannot offer more than 2,050 kilograms' (4,510 pounds) resistance, while the attacking force may reach a maximum of 4,860 kilograms (10,692 pounds).

D.—*Comparison of long- and cross-tie systems.*

The former, if perfect, like all superstructures with single supports, is superior in regard to an even uniform transmission of the force waves which form under the moving loads. The many supports of a cross-tie system exert a disturbing influence on this wave movement, in consequence of which the rail is not uniformly utilized. Therefore, in any cross-tie system, rails must wear unevenly.

It follows that on long-tie systems, smoother rolling of cars, and less wear of all parts, must result than on cross-ties; yet it is possible to get sufficient satisfaction in this respect from the latter system.

Of more importance is the greater security of long- than cross-tie systems against side strains and consequent breakage of rails.

By use of bed-plates on each tie or enlargement of rail foot this objection can be overcome.

In regard to drainage no satisfaction has as yet been obtained in the long-tie systems. The quantity of bed material needed amounts to the same in both systems. Replacement is probably cheaper with cross-ties. Metal weight is alike, yet in long ties the wearing parts are the lightest.

The author concludes that, as only two points are in favor of the long-tie system, which can partly be attained in cross-tie systems, the latter will remain the standard.

MATERIAL.

Although steel is preferable to iron for surfaces liable to wear, like those of rails and tires, yet it presents drawbacks in the case of parts subject to deflection only, as bridges and ties, and being brittle in winter, requires special precautions while cooling after leaving the rolls.

The strength of an iron tie should be much greater than a wooden one, because the former must offer sufficient resistance to deflection over its whole surface, however well it may be packed, as the reactions of the ballast during the passage of trains are distributed uniformly over the whole of the packed portion.

The faults in construction of iron ties were eliminated in those made of steel, which are not liable to split and break, as are the iron ties.

The first trials with hard-steel sleepers were not encouraging. Yet some companies have laid test lines, inspected them carefully, and have kept records as to cost of maintenance (especially in Germany and Holland), and from these trials are derived the results and experience now available in regard to this material.

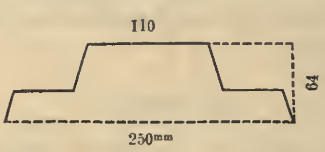
Steel ties, however, have come seriously into competition only since the increase of mild-steel production. This material is less liable to breakage than ordinary steel and less injured in punching the holes for fastening. A steel is used with a tensile strength of 25.4 to 28.6 tons per square inch, and a minimum contraction of 30 to 40 per cent.*

SHAPE.

The great number of forms of metal ties and the modes of fixing the rail to the same must be puzzling to an engineer who has to select one of them. The simpler the plan the better. If equal safety is to be obtained, the metal tie must be of equal size and cover as much surface of the ballast as the wooden tie. Yet the amount of bearing surface of the tie on the ballast, provided this be of good quality and incompressible, is of less importance than that the pressure exerted by the ballast on the underlying soil, which is often compressible, be distributed over the largest surface possible. It is not necessary that the ties have a large bearing surface on the ballast, nor that they be flat on their underside, but only that there be sufficient width between the outer edges.

To meet the requirements of a good tie, which with the smallest amount of material possesses the greatest possible strength, affords a rational distribution of the pressure on the road-bed, and lies solidly in the road-bed, the profile is of great importance.

The form adopted by the Prussian Railway seems to answer well these requirements. It is a box, with the addition of broad flanges at right angles to the sides of the box, at the end of which two short feet permit a secure hold in the bed material. A cross-section presents about this shape:



Many different patterns are in use, like the Vautherin, Elberfeld, Prussian, Rhenish, Austrian, and Webb's ties, on the London and Northwestern Railroad, with a chair for bull-head rail.

Recent improvements in rolling machinery allow the making of ties of varying thickness and having the 1-in-20 slope for the rail made in the process of rolling.

By this a saving of 12 to 21 per cent. and a distribution of material to points where most required is possible. The minimum cross-section is kept for about two-thirds of the length, while under the rail and for a short distance on each side of it, it is thickened.

The Netherlands State Railway, after many tests under various conditions, sharp curves and gradients, with iron and steel ties of various designs, and after carefully comparing cost of maintenance with that of similar lengths of line laid on new oak ties, has decided in favor of a mild steel tie, 8 feet 6 inches long, 9.25 inches wide over the extreme edges at the bottom, 2.52 inches deep for the greater part of its length, but increased to 2.92 inches under the rail and 3.23 inches at about 4 inches outside the rail, so as to give the inclination of 1 in 20 for the cant of the flat-bottomed rail, which rests directly on the tie.

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* See note on jointed cross-ties, p. 125.

The following advantages are claimed for this tie (adopted from the St. Gotthard Railway):

(1) It is easily packed with any kind of ballast—sand, gravel, ashes, slag, stone, etc.

(2) The triangular toe which forms the bottom edge of the sloping sides of the tie prevents damage to the edge during the beating up of the ballast, and by lowering the neutral axis of the section additional stiffness is gained.

(3) It gives a broad surface for the foot of the rail to rest upon.

The weight of the tie is 104.7 pounds, saving 15 per cent. from the weight of a tie of the same strength but uniform cross-section.

The ties ordered in July, 1885, including a two years' guarantee, cost about $1.15 per tie, or "almost the same as an oak tie."

As to form, the closing of the end of the tie deserves special attention. It should have a sloping, closed end, which tends to drive the ballast in under the rail instead of out from underneath, as the early open-ended form did.

WEIGHT.

As stated before, the first iron sleepers were not successful, on account of their light weight and consequently reduced section. Those introduced in France and Germany in 1864 were only 66 pounds. The fastenings had not hold enough and breaking was frequent where the rails rested on the ties; there was also danger connected with them on account of unsteadiness and increased lateral movement. The results were due to the following causes: 1, the holes of the fastening reduced the cross-section; 2, the punching of the holes made the metal around them more or less brittle; 3, in time the foot of the rail and fastening would eat into the top of the tie; 4, with a rational beating up of the ballast the momentum of reaction of a ballast is a maximum at the cross-section, where the wheel load is applied; 5, the impulse of the moving load is transferred directly to the tie at these places.

Increase of weight gives more stability to superstructure. Metal cross-ties weighing 100 pounds have proved quite satisfactory. Those of less weight, 77 to 88 pounds, proved too light. The State Railway of Wurtemberg uses ties of 128 pounds, but the majority of German and Dutch engineers consider 112 pounds fully sufficient to maintain a perfectly steady and permanent road.

The following table, giving the weights and prices used by the different German roads, may be of interest:

Name of railway.	Weight of tie.	Average price per ton of metal.	Average price per tie.
	Pounds.		
Imperial Railway in Alsace-Lorraine	126.5	$31 68	$1 79
Bergisch-Markioch, old Vautherin pattern	126.5	30 96	1 75
Same, New Hilf pattern for main lines	98	30 96	1 35
Same, for branch lines	88	30 96	1 22
Links Rheinisch Railroad, old pattern	77	34 48	1 19
Same, new pattern	110	34 48	1 70
Rechts Rheinisch	106.5	30 70	1 46
Prussian State lines, various	114.5	34 48	1 77
Magdeburg section	120	36 77	1 97
Rechte Oder Ufer	101	42 08	1 90
Hessisch-Ludwigs	98	31 68	1 38
Altona-Kill	101	....	1 60
Wurtemberg State lines	130	37 00	2 14

FASTENINGS.

The subject of fastenings is of greater importance as regards the prevention of shocks between the rails and ties than in preserving the gauge. Whatever the method adopted for attaching the rails to the ties, it must be better than that hitherto employed for wooden ties, and keys are decidedly preferable to bolts, the threads of which rust out so that the nuts cannot be tightened. Yet there are systems of fastening steel ties which are *safer* and more easily maintained than those for wooden ties. After many years of trial, the Netherlands State Railway Company have decided to keep to bolts as the means of attachment between the rail and sleeper. In 1865 they laid 10,000 iron sleepers, fastening them by 4 bolts (0.42 inch diameter) to each tie. In 1883, for the first time, it was necessary to renew 2,000 of these 40,000 bolts, and in August, 1885, the remaining 38,000 were still in use. This shows that the bolts 0.86 inch in diameter now used will be satisfactory. The bolt holes in the ties are square, except that the corners are slightly rounded. It is proposed to retain the cast iron chair, which has rendered good service, especially with Vignoles rails, and to connect each pair of chairs by two bars of Z-section, capable of standing a deflection of nearly 4 tons per square inch, keyed to them so as to form a trough turned either upwards or downwards.

The points for consideration in fastenings are:

(1) By the insertion of a plate between the hard rail-foot and the softer tie, the latter should be saved and its natural straightness preserved, avoiding injuries in the shaping by rolls, in bending, or otherwise.

(2) A rational and direct transmission of the attacking forces from the rail to the tie should be effected.

(3) The fastenings must be such as to keep the gauge constant in the

curves as well as on the straight road, and to permit the elimination of unavoidable faults occurring in fabrication.

(4) To allow shiming up, where the action of frost makes it necessary.

The forces which work upon the fastenings are:

(1) The horizontal forces tending to press the rail-foot outward.

(2) The vertical forces tending to raise the inner edge of the rail-foot.

To counteract these forces, it is necessary, with bolt fastenings, to protect the bolt in its entire length against side forces tending to bend it or wear it away. To effect this the bolt must be placed as near the rail foot as possible, so as to reduce the leverage of the vertical force as much as possible. Small number of parts and a simple form is most desirable.

The nature and good service of the fastenings has also great bearing upon the cost of keeping the road in order.

LIFE.

The life of iron ties has been variously estimated by those in favor of the system at from thirty to fifty years; opponents place it at not more than twenty years, that of the best wood ties. This last estimate is, however, disproved by the more than twenty years' experience with longitudinal ties on the Brunswick railways. These were laid in 1864, and in 1882, on thorough inspection, were found but slightly affected by rust.

In fact, iron ties suffer less from atmospheric influences than wooden ones.

Ties on the Bergisch-Märkisch lines, after being laid for eight years in a badly-drained ballast, were found to be not more affected by rust than the rails.

Mr. Kalff, at the convention in Brussels, stated that metal sleepers laid down twenty years ago were found in perfect condition. Only, for ties kept in reserve by the side of the line or in damp tunnels and similar localities, or if transported over the sea, a coat of tar or paint might be found advisable.

With the better form and heavier sections now used, the breaking of a tie is so unusual as not sensibly to affect the annual charge.

Whatever the cause, steel rails and ties undoubtedly rust much faster than those made of iron.

Mr. P. H. Dudley, C. E., an expert on railroad matters, says: "So far as atmospheric agencies are concerned, the German experience would be a good guide here. The oxidation of rails at least shows in most localities no greater rapidity than in Germany. Failure in this country of metal ties, as far as I have seen them used, was due to their form not meeting the conditions required of a metal tie."

INFLUENCE ON ROLLING STOCK, RAILS, AND ROAD-BED.

The effect of the material of the tie on the rolling-stock is difficult to ascertain, and not much is known about the influence of metal ties.

But it may be noted that on the German railways in 1883 the number of tire breakages per 100 miles of line with wooden ties, metal cross-ties, and metal longitudinal ties, were respectively as 7.25 to 5.96 to 2.74; showing the advantage of the long-tie system, by which the shock at rail-joints especially is diminished.

The weight of the entire superstructure in itself and the good tamping of the ballast conduce to its quiet position, and serve to lessen the loss in rolling-stock and the cost of maintenance.

C. P. Sandberg, the well-known expert on rails, says:

> "It is a great mistake to diminish the rail section in consequence of the adoption of metal ties, as has been done on some railroads, for the metal in the tie can in no sense make up for the metal in the rail. The strong rail has the power of spreading the effect of the concussions from the rolling stock over several neighboring sleepers, thus dividing the effect, while the light, weak rail will concentrate the blows on one or two ties.
>
> "The heavy flange rail also is a *sine qua non* for the success of a metallic permanent way; if by 'permanency' be meant anything approaching thirty years or more."

In the Revue Générale des Chemins de fer, April, 1886, p. 260, a comparative table is given, showing the respective durability of rails on ordinary roads with wooden cross-ties, and roads on metal ties with the Vautherin and the Hohenegger system (longitudinal ties 32 feet long with one cross-tie to each length), and the Hilf system (longitudinal tie of 24½ and 29½ feet length with one cross-tie to each length).

The comparative results show: (1) That with the Vautherin system the wear is three times as much as with good wooden ties; (2) with the Hohenegger system the wear is four times as rapid; and (3) with the Hilf system it is four to five times as rapid as with wooden ties.

Metal ties do not *bend* visibly like those of wood, but descend evenly, and the leverage of the momentum of deflection at the intersection of the rails and ties is greater than in the case of wooden ties; but if the strain be limited to, say, 4 tons per square inch for iron, and about half as much again for steel, there is no fear for the resistance of metal sleepers.

If the ballast inside the rails has not been properly packed, so that only the portions outside the rails sustain the whole load, the momentum of deflection will double, but even then there will be nothing to fear; but if, on the contrary, only the central portion of the tie between the rails bear upon the ballast, the maximum momentum of deflection, which may thus be increased to five times its ordinary amount, will be transferred to the center of the tie.

Experience has shown, however, that this will not occur if care be taken not to pack the central portion of the tie.

Filling hollow sleepers with ballast having a certain amount of cohesion is not recommended, as no degree of elasticity in the filling substance can increase the resistance to deflection. The tamping of the ballast under steel ties must be so done that the middle of the tie is either empty or at least not compactly filled with ballast, while for a distance of 12 to 15 inches on each side of the rail the ballast must be well tamped.

It is also important that during the first few months after the ties are laid the road should have great and constant attention until the bed becomes consolidated. The cost of this ought to be considered as part of the cost of laying the road.

The metal tie acts best on firm ground. Thus on the Liége-Limbourg line there were 20,000 metal ties which had not been touched for twenty-two months and the road continued in a most satisfactory condition, working trains running at a maximum speed of 38 miles per hour. Lengths of ballast of medium quality in which wooden ties appeared to be dry have proved unsatisfactory with iron ties. By means of their pumping action the latter draw the wet up from below and work the ballast into mud, making a solid bed impossible. This working up into mud occurs also with wooden ties, but only after the ballast has become completely impermeable for water, and requires renewing anyhow.

The reasons for this difference may be stated as follows:

(1) The iron ties have twice the deflection of the wooden ones.

(2) On account of the accurate fastening of the rail to the iron tie, it shares the whole vertical motion of the rail, whereas with wooden ties the play of the foot of the rail in the dogs and the compressibility of the timber both tend to lessen the deflection of the tie.

(3) The hollow body of the iron tie is very favorable to the formation of an air-tight cavity, inducing the pumping action above referred to.

(4) The under surface of the wooden tie lies twice as deep as that of the iron one.

The working up of the ballast into mud by iron ties, on certain trial lengths, has interfered with their more general introduction, whereas the failure should have been put down to the inferiority of the ballast and its impermeability to water. It would be found that in similar ballast an accumulation of moisture at the bottom of wooden ties takes place.

Good ballast must fulfill the following two conditions:

(1) It must be capable of being beaten up under the tie into a firm mass so as to afford the greatest possible resistance to the deflection when the load comes upon the tie and the greatest possible resistance to being shaken loose.

(2) At the same time the material must be such that between the ties there may be in it interstices for the passage of water, but also the greatest possible cohesion and friction, to prevent slipping and to distribute equally the pressure of the load.

Broken stone fulfills these conditions best, especially as to drainage.

Water remains longer between the rails and ties with the longitudinal tie-systems than with that of cross-ties, as on account of the solid body below it is drained off more slowly; therefore in winter the gravel bed forms a frozen body. If this thaws from above, the long tie may lie entirely in a thawed bed and the cross-connection in a frozen bed. Then the cross-connections are points between which the long ties with the rails must lie free or imperfectly supported. From this occurrence danger must be apprehended, especially in changing weather.

Another objection is made on account of frost-heaving. If in a wooden structure one rail is thus lifted, the other can be accommodated. But in iron structures a greater diversity of heavings must occur, which are not so easily remedied.

The Royal Prussian Railway management, however, using Haarman's long-tie system, finds this objection not sustained even in protracted frost weather, and considers this system efficient as well as easily and cheaply maintained.

On the Braunschweig railroads the iron superstructure (long tie) upon hard subsoil is not easily maintained in wet weather.

The same experience has been made in Lorraine.

But on the Rhenish system, on well-drained ground, no difficulty is experienced.

On the road from Calbe to Blankenheim (mountainous), where more than 60 miles of Hilf long ties are laid, the cost of maintenance is double that of wooden ties, the reason among other causes being the bad condition of the bed material, a loamy and clayey sand, which becomes slippery after every rain.

A simple cross-tie system and broken-stone ballast is recommended on badly drained soils.

COST.*

The item of cost is naturally of primary importance with good financiers, but for a perpetual concern like a railroad the first cost is not always the most important factor of calculation.

In fact, the saving of labor for renewals and maintenance is now the vital question in the cost of railroad working. When this is brought to a minimum by perfection of road, safety and comfort in traveling, as well as a dividend, will be secured.

According to Sandberg, who advocates only the most solid structure, the desirable metal tie may be said to cost as much per ton and weigh as much per mile of line as the rails themselves.

Gustav Meyer says:

> "Iron cross-ties of 110 pounds weight, costing $1.73 each, must last twenty-five years in order not to involve an annual charge of more than 9.8 c. (average annual charge for wooden ties on German roads)."

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* For original cost of metal ties now in use, see table, p. 118.

To get at the annual cost for the provision and renewal of railway ties the following points must be considered:

(1) The annual interest on first cost.

(2) The annual sum laid aside for depreciation.

(3) The "old material value," lessening the amount of depreciation.

(4) Cost of labor and tools for replacing ties.

(5) Cost of the attachment to the rail.

(6) Cost of maintenance in the road-bed.

(7) Influence of tie upon the life of rolling-stock.

The first cost of fastenings for wooden ties is less than for metal ones, but the cost of renewal is greater in the former case, so that in the end the annual cost for fastenings becomes less in the case of metal ties.

The cost of maintenance of a steel-tie road three and one-half years old was found the same as that of one of the same age laid on wooden ties, but from this point on the cost of the latter increases, while the cost of the former tends to diminish, owing to the consolidation of the bed. One of the district engineers of the Netherlands Railroad states that on a test piece of 1,144 yards, on a curve of 820 yards radius and a gradient of 1 in 83, no tamping of the ballast was required for 22 months ending December 31, 1884, and that the only maintenance required was one man for 34 days inspecting and tightening up bolts.

On the Rhenish roads, which at the end of 1879 had 112 miles of track laid with longitudinal, and 197½ miles with cross metal ties, and to which, during 1880, were added 94 and 138 miles, respectively, the following results were obtained: On 100 miles of track with wooden ties 271 labor days were required yearly; with metal longitudinal system, on an average of three years, only 258, or 5 per cent. less, and the average amount of labor expended in the year 1879 was only 209 days, or 23 per cent. less; with iron cross-ties, during an average of 25½ months, 242 days, or 11 per cent. less, and for the average of the year 1879, 164½ days, or 35 per cent. less were required.

In Germany the cost of maintenance has been found to vary from $38 to $360 per mile with long-tie system, and from $47 to $107 with cross-ties, subsoil, bed material, and kind of structure causing great differences.

Taking (1) the annual interest on first cost (C) at 5 per cent. (or 0.05 C).

(2) Annual allowance (B) to be charged for renewal after n years, leaving out of account value of old material:

$$B = \frac{0.05}{1.05^{n+1} - 1.05} C.$$

(3) The reduction of this (B) annual allowance due to value of old material is:

$$\frac{0.05}{1.05^{n+1} - 1.05} \times \text{value of old tie.}$$

(4). Annual amount to be allowed (x cents) for cost of changing tie after n years is:

$$\frac{0.05}{1.05^{n+1}-1.05} \times x \text{ cents.}$$

Taking the value of old wooden tie at 10 per cent. of first cost, that of old iron sleeper at 40 per cent., it would be found that a wooden tie of $1 first cost and 12 years' life costs 10.2 cents per annum exclusive of maintenance, while an iron tie of $2 first cost, lasting 30 years, costs 9.8 cents per annum.*

Another writer inquires how much more a metal tie will cost than a wooden one, if the former would last double the time of the latter and its value as old material be considered 40 per cent. of its first cost ($O_{,}=0.4\,N_{,}$), while that of the old wooden tie is taken as 10 per cent. of its first cost ($O_{,,}=0.1\,N_{,,}$). The cost of renewal ($R=N-O$) is, in the case of the metal tie, $R_{,}=0.6\,N_{,}$, and for the wooden tie $R_{,,}=0.9\,N_{,,}$.

The annual charge for renewal (r), if life of ties is set at $n_{,}$ and $n_{,,}$ years, and the rate of interest at p per cent., may be expressed:

$$\left(\text{setting } \frac{100\times p}{100}=e \text{ as}\right)$$

$$r_{,}=0.6\,N_{,}\,\frac{e-1}{e^{n_{,}}-1} \text{ for metal}$$

$$r_{,,}=0.9\,N_{,,}\,\frac{e-1}{e^{n_{,,}}-1} \text{ for wood,}$$

and these amounts capitalized (that is to say, the capital R, the interest on which at p per cent., will furnish the required amounts of yearly charge for reserve fund),

$$R=\frac{r}{e-1} \text{ would make}$$

$$R_{,}=\frac{0.6}{e^{n_{,}}-1}N_{,} \text{ for metal.}$$

$$R_{,,}=\frac{0.9}{e^{n_{,,}}-1}N_{,,} \text{ for wood.}$$

Leaving out all other advantages of iron ties, that is to say, considering only the longer life as the criterion, N' may be taken so high that the first cost of the metal tie, together with the capital necessary to renew it indefinitely, equals the sum of the same items for wooden ties, namely:

$$N_{,}+R_{,}=N_{,,}+R_{,,} \text{ or } N_{,}=N_{,,}+R_{,,}-R_{,};$$

and by substitution

$$N_{,}=\frac{(e^{n_{,,}}-0.1)\,(e^{n_{,}}-1)}{(e^{n_{,}}-0.4)\,(e^{n_{,,}}-1)}=N_{,,}$$

If, then, $n_{,}=2_{n_{,,}}$, that is to say, if the metal tie last double the time of he wooden tie, the cost of the first may be

$$N_{,}=\frac{e^{2n_{,,}}+0.9e^{n_{,,}}-0.1}{e^{2n_{,,}}-0.4}N_{,,}$$

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* See table on page 118; also bottom of page 122.

From this may be calculated at a rate of interest of 4 per cent. for a wooden tie lasting ten years, $N_{,}=1.9N_{,,}$, and compared with a creosoted wooden tie lasting twenty years, $N_{,}=1.5N_{,,}$; that is to say, if the metal tie lasts twice as long as our best oak ties, its original cost may be allowed to be nearly twice as much as the oak tie. If it lasts twice as long as a creosoted tie of twenty years' duration, it may cost one and one-half as much as this to be only equally as expensive; if duration and cost of renewal alone are considered, or, as our best oak ties do not average more than eight years' life, and a metal tie can be safely said to last three times that period, reckoning rate of interest at 5 per cent., at present prices for metal, and considering cost of renewal, it would be economy to use metal ties when oak ties cost 70 to 80 cents, and pine ties lasting five years cost 50 to 55 cents.

ADDENDA—JOINTED AND COMPOUND CROSS-TIES.

As the object of these notes is to point out where a saving in the use of wooden material for railroad construction may be effected, the following suggestion may find proper place here, describing a system of using up old wooden ties practiced on the Netherlands State Railways.

The best wooden ties fail at the point where the rail rests on the tie, while a length of from 3 to 3¼ feet between the rails remains quite solid. Laying two such lengths sawed off end to end, they are joined together by a length of inverted channel iron let into the timber, so that its web lies upon the upper surface. The rail rests on the channel iron, which thus prevents it from wearing into the tie. (By bending, the 1-in-20 cant, if required, can be given.)

The sawing, dressing, boring, and putting together of these compound wooden and iron ties can be done in wet weather by the trackmen, thus saving in the cost. The laying and batting-up are the same as with ordinary ties.

As these compound ties have four end-faces, they offer increased resistance to lateral motion.

In July, 1882, a quantity of these ties were laid in a main line through a station, and in September of the same year, a further number on a main line curve of 50 chains radius and a gradient of 1 in 62, over which ran thirty trains a day, some of them expresses. Both of these lengths have required no different treatment from the adjoining lengths laid with ordinary wood ties, while the gauge has remained exactly true.

In a similar manner may be joined together short metal waste pieces which are left in making steel ties, in order to reduce the price of the perfect steel tie, the waste pieces being riveted together. This attempt to produce a cheap steel tie, at least for secondary lines, may be considered quite successful.

The Netherlands State Railway in June, 1885, laid a number of such ties on a curve of 26 chains radius with a gradient of 1 in 62. These ties have shown no disadvantages during loading, unloading, laying, or batting-up, and have required no more tamping than ordinary ties near them.

There are six different types of these riveted ties, in all of which the rivets are 0.79 inch diameter.

The joint may be 6 inches from the center of the tie, so as to allow of short pieces being used up.

Another proposition for the use of waste material in the construction of steel ties is to cut old steel rails (Vignoles section) into lengths of 7 feet 10 inches and rivet them to cast-iron chairs (those used with Vignoles rails), two lengths to each pair of chairs, thus forming a cheap, strong, and durable tie, which will be worth as much as new ties would be after both have served their turn, while at the same time using what is now a drug in the market.

The newest proposition is, for the sake of cheapening iron ties, to employ soft cast-iron, avoiding the expense of rolling, or, rather, for the same price to give more material and more weight to the tie.

Such ties are made at Halbergerhütte, near Saarbrücken, Germany, and are capable of being deflected (slightly) without breaking, and are tough enough not to break on being dropped by the men handling them. They cost $1.60 per tie and weigh 220 pounds, instead of 110 pounds, the weight of the Haarmann tie.

To obviate the objection of danger from spreading of gauges, the writer proposes to combine with this cast-iron tie a wooden one, for the purpose simply of holding in place bolts or spikes and preventing the spreading. The wooden ties thus used are only one-third of the thickness of those now in use, allowing a saving of material. Longer bolts or spikes (by the thickness of the iron tie) are to be used.

The additional cost of this construction, taking original wooden ties at $1.20 (now $\frac{1}{3} = 40$ cents) and ten ties for 100 feet of rail, gives $\frac{10}{30} - 5280 \times 40$ cents = $7.04 increased cost ($\frac{10}{9}$ a mile).

The Webbs metal superstructure, introduced on the London and Northwestern Railroad, consists of steel ties (Vautherin profile), with six holes for chairs to be riveted to the tie. The chair consists of three parts, bottom plate bent to correspond to rail foot, and two side plates, the interior one adjusted to the rail profile below top flange, the outer allowing a space for the reception of a wooden wedge, which tightens the rail in the chair. The tie is 10 feet 7 inches (2.7 meters) and weighs with chair and bolts 175.6 pounds (78.9 kilograms).

The newest system proposed and introduced on their roads by the Bureau du Materiel fixe de la Compagnie des Chemins de fer de l'Est, in Paris, preserves as much as possible the rectangular cross-section of the wooden tie, especially the flat underside, which is important for a good underbatting; it combines wood and iron as did the earlier system of Cozyns and Debrières in 1862. It consists of a simple box with the two ends somewhat curved instead of being rectangular; upper width of tie 250 millimeters; lower, 220 millimeters; length, 2.7 meters (10.6 feet), diminished by turning down the ends to 2.5 meters; weight, 65 kilograms (143 pounds). The fastening is the important feature of the system, two clamps on either side of the rail, which may be fastened to or cut out of the tie, allowing ample space for the insertion or removal of the rail. A wooden block between the two sets of clamps driven under the rail brings this into place tight against the fastening clamps, which are adjusted to the rail profile. Two spikes driven into the block on the inside of the rail hold it in place.

The International Railway Tie Company at Boston offer a steel tie which has for a short time been in experimental use on the Boston and Maine and Maine Central Railroads. It is of simple construction, weighing 150 pounds, and can be made at $1.25 per tie. The only objection to it so far found has been a tendency to blow out the ballast, as might have been expected on account of the open ends of the tie. According to latest advice improvements in the construction of the tie remove this objection, and by simplification the price can be reduced to nearly 75 cents per tie.

The Des Moines Street Railway Company have laid 1,000 metallic ties of the Johnson Street Steel Rail Company's pattern, weighing 30 to 40 pounds and costing $1.25 per tie, the rail fastened with clamps, one riveted to the tie, the other braced against a keeper and firmly bolted. The structure lies on cedar blocks with plank flooring. Mr. Frank A. Sherman, secretary of the company, writes after six months' use of the ties: "Aside from the cost (we estimate it as 3 to 1 for oak ties) we believe the metal ties practicable. They are easily and quickly laid, can be removed readily without seriously disturbing pavements, and the rails are firmly fastened to the tie so that spreading of track is next to impossible."

Appendix 4.

CONNECTION OF RAILROADS WITH FOREST FIRES.

By N. H. EGLESTON, *Agent of the Department.*

Railroads, in addition to the great consumption of the forests involved in their construction and use, as in the production of ties, bridge, trestle and platform timber, as well as building cars and securing a supply of fuel, are very destructive to the forests by means of fires occasioned by their engines. Investigation shows the latter source of loss to be a very serious matter at present, and a more serious one prospectively.

In the census year 1880 an attempt was made, under the direction of the Government, to ascertain the extent of injury inflicted upon the forests by means of fires and the causes by which the fires were occasioned. Thirty thousand circulars making inquiry on the subject were sent out, reaching every town ,in the country. Replies to all of the circulars were not elicited, but it was clearly shown that during the year 1880 not less than 10,274,089 acres of woodland were burned over, involving a loss of $25,462,250.

Among the causes of forest fires, railroad locomotives were reported as among the most prominent, standing third on the list in this respect, only hunters and persons engaged in clearing land having occasioned more. One-sixth of all the fires reported were attributed to them. Another and independent investigation attributed one-eighth of the forest fires to this source.

The published reports do not undertake to give the extent of each fire, or the value of the forest or other property destroyed in each case. We cannot say with precision, therefore, what was their extent or the damage occasioned by the fires set by locomotives as compared with those originated by other means. But we have 508 fires reported as kindled by railroad engines. How many more may have originated in this way, which have not been reported, we have no means of ascertaining. If we assume that the average amount of destruction occasioned by fires started by locomotives equals that of other woodland fires, then we have 1,712,348 acres of forest consumed and property of the value of $4,244,208 destroyed by these locomotive fires. This amount, therefore, is to be added to the consumption of the forests for ties, bridge timber, &c., in making up the account of the drain upon the forests attributable to the railroads.

The following table shows the percentages of forest fires occasioned by locomotives in the several States so far as ascertainable from the reports received:

Table showing number of forest fires in 1880, acres burned, number of fires caused by locomotives, percentage of these compared with forest fires from all causes, and probable value of property destroyed by locomotives in each State from which reports have been received.

States.	Number of forest fires.	Acres burned.	Number caused by locomotives.	Per cent. of all.	Probable loss by locomotives.	Probable number of acres burned by locomotives.
Alabama	72	569, 160	4	6	$7, 273	34, 149
Delaware	14	3, 305	6	42	6. 583	1, 368
Georgia	54	705, 351	2	4	6, 704	28, 214
Indiana	99	90, 427	20	20	26, 067	18, 085
Iowa	46	11, 017	5	11	5, 001	1, 212
Kansas	10	7, 080	1	10	1, 470	708
Kentucky	106	556, 647	12	11	26, 139	61, 231
Maine	76	35, 230	14	18	22, 197	6, 341
Maryland	66	41, 070	16	24	8, 982	9, 858
Massachusetts	159	13, 899	52	33	33, 746	4, 580
Michigan	267	238, 271	43	16	157, 758	38, 123
Minnesota	84	250, 805	13	15	209, 266	37, 620
Mississippi	39	222. 800	1	3	2, 355	6, 684
Missouri	97	783, 646	10	10	47, 178	125, 383
Montana	5	88, 020	1	20	225, 600	17, 604
New Hampshire	27	5, 954	12	44	27, 988	2, 620
New Jersey	54	71, 074	28	52	131, 154	36, 948
New Mexico	47	64, 034	1	2	2, 950	1, 280
New York	102	149, 491	43	42	508, 530	62, 786
North Carolina	221	546, 102	11	5	17, 899	27, 305
Ohio	192	74, 114	27	14	111, 603	10, 375
Pennsylvania	381	685, 738	133	35	1, 065, 303	240, 008
South Carolina	67	431, 730	1	1 5	4, 308	6, 476
Tennessee	73	985, 430	6	8	420, 398	78, 834
Vermont	18	3, 941	5	28	13, 571	1, 103
Virginia	51	272, 319	13	25	81, 761	68, 080
West Virginia	54	476, 775	7	13	20, 186	61, 980
Wisconsin	108	406, 298	12	11	79, 817	44, 693
Total	.....	....	......	......	3, 291, 847	1, 033, 571
Percentage	.....	....	......	......	12.9 pr. ct.	10.06 pr. ct.

There are some particular considerations in connection with forest fires which make them worthy of special notice. In the first place, in the case of coniferous trees, they may not only consume the ripe timber, causing its total loss, but they destroy the young trees, which would soon replace the full-grown ones and thus continue the existence of the forest. But this is not all. The destruction of the forests by fire is often much more disastrous, attended by effects reaching beyond the simple destruction of growing wood, whether old or young. The lumberman cuts simply the standing timber, leaving the ground to be covered soon by another wood growth, possibly not so good as that removed, but having an appreciable value. In a forest of deciduous trees many of the stumps soon send up copious sprouts, and, if cattle are not allowed to intrude, a coppice will be quickly formed. But where the forest is ravaged by fire, there is involved not only the destruction of the present stand of timber, or at least its great deterioration, but the roots of the trees may also be burned and their vitality destroyed. The tree seeds also, which are in the soil ready to sprout and renew the forest growth, are consumed. The very soil itself is often burned to such a depth that many years must elapse before it will regain the ability to support any useful growth whatever.

Thus it appears that the railroads are not only great consumers of the forests, in a legitimate way, for their own construction and maintenance and by the destruction of standing timber occasioned by fires from their locomotives, but they also take away, in many cases, the reproductive power of the woodland tracts over which these fires may run.

The exposure of forests near railroad lines to destruction by fire occasioned by passing engines operates to discourage the holding or planting of woodland in such situations. In some of our States fires caused by locomotives have become so frequent and destructive that growing timber is regarded as hazardous property. In New Jersey, which abounds in pine forests, the danger from locomotives is so great that timber land near railroads has only a nominal market value. In Cumberland County, in 1880, a fire was started by sparks from a locomotive and spread 10 miles in one direction, consuming from 40,000 to 80,000 acres of forest, involving a loss of $320,000. A correspondent from that county estimates that three-fourths of all the fires in New Jersey originate from locomotives. Great destruction of the forests in Pennsylvania is attributed to the same cause, and the annual loss is estimated at millions of dollars.

The fact that these losses are so great, and that they are not necessarily incidental to any important business; that the destruction of the forests in this way does not, like cutting cord-wood to be burned in the factory, the furnace, or for domestic purposes, subserve important industries or promote human comfort, but is a loss simple and total, appeals to all, to railroad managers as well as others, to employ every practicable means for the suppression of these fires.

LAWS IN REGARD TO FIRES OCCASIONED BY LOCOMOTIVES.

The growth of railroads has given origin naturally and necessarily to a considerable body of law defining and protecting the rights and enforcing the obligations appertaining to railway corporations. This body of law, however, relating as it does to corporate organizations which have come into existence within the last fifty, and most of them within the last twenty or twenty-five years, is not as complete and definite as are the provisions of law which have been longer in the process of formation because relating to matters longer in existence and needing legal regulation. In our own country the responsibility of railroads for damages occasioned by fires kindled by sparks from their engines has been settled by statute in comparatively few cases. It is dependent mostly upon the application of the common law, and the adjudication of this differs in the various States. It is a maxim of that law that one is to use and enjoy his own property in such a manner as will not involve the injury of another. It is held that fire, being a dangerous element, whoever lights a fire, whether in a dwelling, in the field, or elsewhere, is bound to keep it so within his control that it shall not occasion damage to any one else. But he is held only to reasonable care and prudence in this respect, and there is room, in a multitude of cases, for dispute whether there was requisite care or such negligence as to render one liable for damages.

In most of our States, as has been said, the liability of railroads for damage occasioned by sparks from locomotives is determined by the common law. Most of the States, however, have made enactments on the subject. In Colorado, for example, railroad companies are required to have a strip of ground, not less than 6 feet wide, plowed every year between July and October on each side of the line of road, sufficient to prevent the spread of fire. This is not required within the limits of towns or cities, or on roads running through mountains where plowing would be impracticable.

In Connecticut the statute declares the fact that a fire was occasioned by a locomotive shall be *prima facie* evidence to charge with negligence those owning or operating the railroad on which the locomotive was in use. In Massachusetts whoever willfully or without proper care sets fire to the property of another is liable to a fine of $250, and fire wardens are directed to prosecute such offenders.

In Illinois the fact that a fire has been started by sparks from a locomotive is made, as in Connecticut, presumptive evidence of criminal negligence.

The law of Maine enacts that when property is injured by fire communicated by a locomotive, the corporation using it is responsible for such injury, and it has an insurable interest in the property along the route for which it is responsible and may procure insurance thereon.

In Maryland, railroad companies are responsible for injuries occasioned by fire, unless they can prove to the satisfaction of the court that there was no negligence.

In Michigan railroad companies are made liable for all loss or damage occasioned by the engines or employés of such companies. It is provided, however, that they shall not be liable if the engines are in good order and properly managed, all proper precautions are taken to prevent the origin of fires, and proper efforts are made to extinguish fires, in case of their extending beyond the limits of the road, when the existence of such fires is communicated to any of the officers of the road.

In New Hampshire railroads are made liable for all damages. They are also declared to have an insurable interest in all property on the line of the road exposed to damage.

The law of Vermont is similar to that of New Hampshire.

In New Jersey it is provided that engines must have screens, and the fact of fire is made *prima facie* evidence of the violation of the law.

The exposure of the railroad companies to complaints on account of fires originated by their locomotives, and to suits at law for damages, as well as other reasons appealing to their self-interest, have led to many and protracted experiments for the purpose of preventing damage to property arising from this source and inconvenience to passengers. Many contrivances for this purpose have been tried. Some have been, in a degree, successful, but most of them have proved failures in practice. Within a few years, however, spark-arresters have been devised which railroad engineers and managers declare to be so efficient in securing the end desired that it would seem to be imposing no hardship on the railroad companies to compel them by law to furnish all their locomotives, as a condition of their use, with one or another of these safeguards. An eminent expounder of the English common law says that though railway companies may be expressly authorized by statute to use locomotive furnaces of a dangerous character, "no statute can exempt them from the consequences of negligence in the management of their railways, or the construction of their fire-boxes, chimneys, or furnaces whereby coals of fire are thrown on the adjoining property. If they neglect to avail themselves of all such contrivances as are in known practical use to prevent the emission of sparks from their engines, they will be responsible for such neglect, and if they run locomotives without statutable authority, in that case they are responsible for any damage caused by such engines in setting fire to adjoining property or otherwise, although they have not been guilty of negligence."

It would seem that our interpretation of the common law should be as effective as that of England in protecting property from destruction by fires originating from passing locomotives, or that our statute laws should be made to accomplish the same end.

SMOKE-CONSUMING DEVICE FOR LOCOMOTIVES.*

By J. N. Lauder,
Superintendent of Motive Power, Old Colony Railroad.

In presenting this paper on smoke-consuming devices for locomotives, it is not my purpose to enter into the details of the mechanical construction of the various devices that have been experimented with in a practical way during the last thirty years, or, to speak more accurately, ever since the locomotive was brought into existence, but to give, in a general way, what has been done in the past and what is being done at the present time to mitigate the evils of the discharge of unconsumed products of combustion from the chimney of the locomotive.

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* Reprinted from the Proceedings of the American Forestry Congress at Boston, Mass., 1885.

The smoke and sparks that are discharged from the locomotive are so annoying to passengers that on some of our lines a trip by rail on a hot day is something to be dreaded, and the danger to forests and other property from fires set by these sparks is, in the aggregate, enormous.

To the novice the remedy for all this would seem to be to so arrange the furnace that perfect combustion would take place. This may be done on stationary or marine engines, where heating surface enough can be provided to allow of slow and perfect combustion, but in the locomotive the weight and size of boiler is limited and artificial means must be used to provide for such rapid combustion as is required when the engine is developing its full power.

The attention of locomotive mechanics has been drawn to this question of fuel-combustion ever since the birth of the locomotive, but their efforts to make it perfect have been only partially successful, and while the heating surface of our boilers is so small in comparison with the requirements of the engines a forced draft will have to be resorted to. This fact being recognized, it necessarily follows that when the engine is developing its full power the artificial draft is so strong that small particles of coal will be lifted from the fire and drawn through the flues unconsumed and discharged out of the chimney in the form of what is called sparks. The fact that some solid matter will be drawn through the flues from the fire being established, I will now briefly consider the various mechanical contrivances that have from time to time been brought forward to arrest and dispose of these solids.

Among the earliest contrivances (when wood was the universal fuel used in this country) was a chimney shaped like a funnel placed with the broad mouth upward. This broad end was covered with a wire screen, and inside of this chimney was placed a straight pipe somewhat smaller than the smallest diameter of the chimney, its height being about two-thirds that of the chimney. Over this, and near the wire screen, was mounted a deflecting plate with edges curving downward. A spark-reservoir was placed in some suitable position near the smoke-box, and pipes were made to lead from the annular space between the chimney and the inside pipe to this reservoir. The operation of this arrangement was as follows:

The unconsumed products of combustion that were drawn through the flues were driven by the exhaust steam upwards against the curved deflector at the top of the chimney, and the larger and heavier particles were forced down and into the spark-reservoir. The lighter particles would pass to the atmosphere through the wire screen, but would rarely have life enough to set anything on fire. The reservoir, however, was soon abandoned, as it was found in practice that with wood for fuel the sparks were so reduced in size by friction in their passage through the flues and chimney that they could all pass through the screen to the atmosphere with little danger of setting fires.

When coal came to be used as fuel the old arrangement of chimney was found to be unsuitable, and new appliances had to be devised. A new and annoying element had to be met—that of gas and smoke, caused by imperfect combustion in the furnace. When fresh coal is added to the fire a vast quantity of gas is evolved and unless a sufficient quantity of atmospheric air is brought into immediate contact with it, it will pass off in the form of smoke.

Various plans to furnish the requisite amount of air, and at the proper time, have been tried, but the varying conditions under which the engine is working have so far made it practically a failure.

Letting air into the furnace over the fire, while it will prevent the formation of smoke if let in in sufficient quantity, will also lower the steam-producing qualities of the boiler. Air mixed with a jet of steam driven into the furnace over the fire has been tried at various times and in various ways, but it has always ended in failure. D. K. Clark, the eminent English engineer and author, in his work on the locomotive, describes a method of injecting air and steam mixed into the furnace of a locomotive boiler to promote the combustion of the gases.

Recent so-called inventions brought out in this country are almost exact duplicates of appliances described by Clark long ago.

Rotary blowers have been used to drive the products of combustion from the smoke-box back to and into the furnace to be subjected to a reburning process, but such methods never got beyond the experimental stage. Double or twin furnaces have been tried, but while producing good combustion the mechanical difficulties to be overcome have thus far interfered with their success. Several years ago mechanical devices of various forms were quite largely used for driving the solid, unconsumed products of combustion from the smoke-box back through suitable tubes to the furnace, but they have nearly all given way to more modern and better methods.

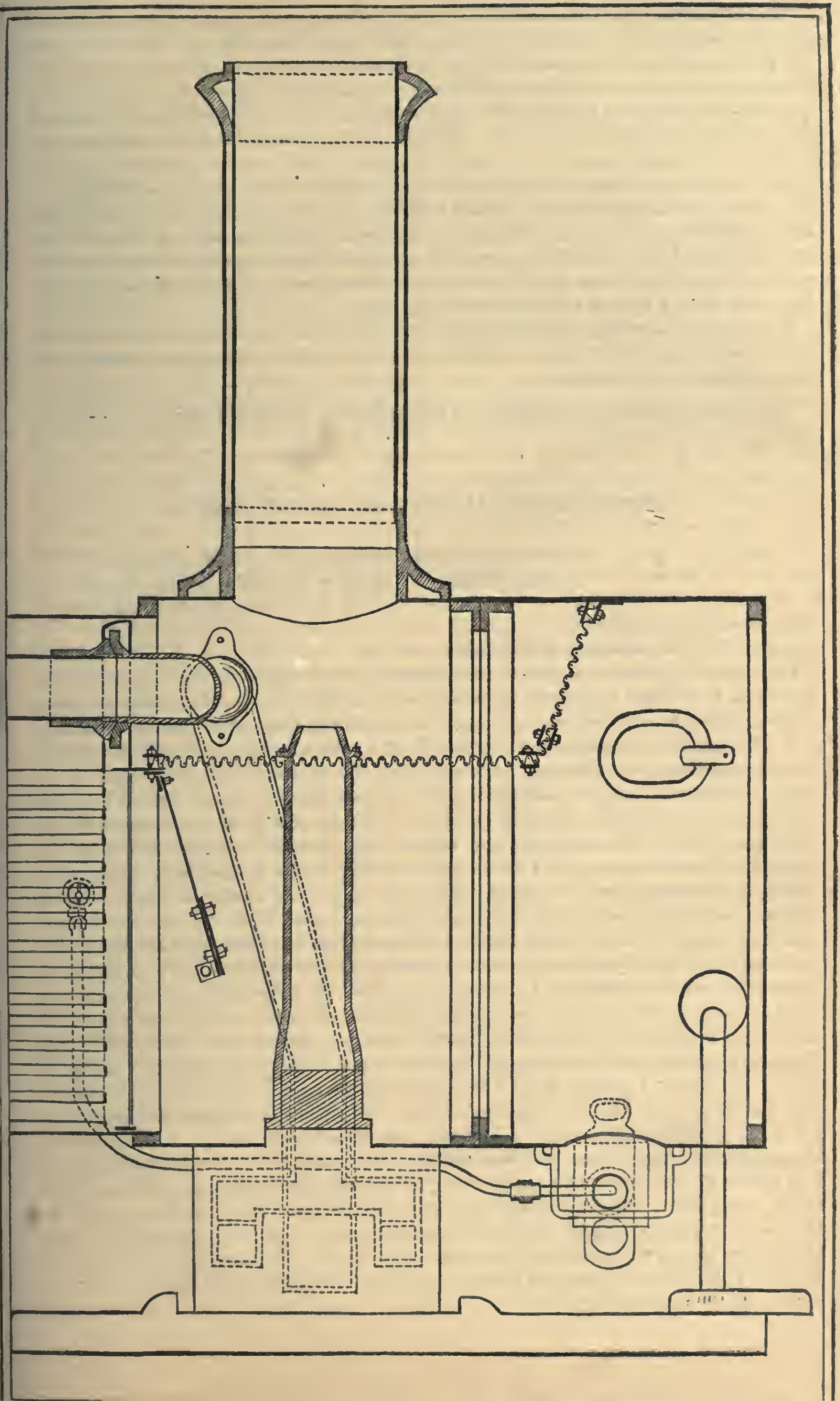
I will now proceed to discuss the most approved methods of promoting combustion, and also the mechanical means employed to prevent the escape of sparks from the chimney. And here let me say, curious as it may seem, the wonderful discoveries made in the last twenty years in the production of steel have a direct bearing on the question under discussion.

The substitution of steel for iron in rails and tires has made it possible to so increase the weight of the locomotive that larger boilers can be used, and therefore a very much greater heating surface in proportion to the cylinder area. This fact makes it possible to do what could not be done were soft-iron rails and tires still in use.

The modern locomotive boiler has little to distinguish it from its prototype of thirty years ago. All combustion chambers, water tables, and complications of all kinds have been discarded, and we have the plain rectangular furnace, with plenty of tubes to freely carry off the products of combustion. Its leading feature is its size and large heating surface. Its enormous evaporative power will be recognized when I say that this boiler, when pushed to its full capacity, will convert 3,000 gallons of water per hour into steam. To accomplish this amount of work on a grate surface of only 18 square feet, very rapid combustion must be maintained, and this can be done only by a forced draft. A forced draft means imperfect combustion, and imperfect combustion means particles of unconsumed coal drawn through the tubes. These unconsumed solids must be arrested in their course to the atmosphere and deposited in receptacles where their presence will not be harmful. This is measurably accomplished by the use of the appliances shown in the drawings. The smoke-box is made twice the usual length; a coarse wire-screen is drawn across high enough to be above all the boiler flues; the chimney is a plain, open pipe, smooth and free from obstructions.; the exhaust pipes are carried up through the screen, terminating in a single nozzle. In front of the flues a deflecting plate is placed at a suitable distance from the ends of the flues, and is set at an angle of about twenty degrees. The functions of this plate are twofold—first, it equalizes the draft through the flues; and, second, it deflects the sparks downward, and instead of their being shot upward through the chimney they are banked up in the forward end of the smoke-box, there to remain until they are removed at the end of the trip. In the furnace is placed a fire-brick arch, extending entirely across the furnace and from the flue-sheet under the flues back about two-thirds of the length of the furnace. The gases, as they arise from the coal, are forced to travel back and over this arch on their passage to the flues, and by the delay thus caused, and also by their contact with the intensely hot fire-brick composing the arch, are very thoroughly consumed. The unburned solids lifted from the fire are also prevented from being drawn directly into the flues, the force of the draft caused by the exhaust steam in the chimney causing them to impinge against the hot brick, where the heat is so intense that a large percentage of them are consumed that would otherwise be drawn through the flues in a solid state. The brick arch is supported on four iron tubes, placed diagonally in the furnace, connecting the water-space under the flues with the water over the furnace crown. These tubes not only make a reliable support for the brick, but best promote the circulation of the water in the boiler.

The arrangement of smoke-arch described is not of recent design, but was patented

PLATE II.



in substantially its present form about twenty years ago by Mr. John Thompson, of East Boston, who was then connected with the Eastern Railroad in the capacity of master mechanic. It was tried thoroughly by him at that time, but was abandoned for the reason that a comparatively few miles run would fill up the smoke-arch with sparks and so interfere with the draft that the capacity of the boiler to generate steam in sufficient quantities to supply the wants of the engine was destroyed. The small furnaces used at that time and the powerful artificial draft made necessary thereby produced this result.

As I stated in a former paragraph, the introduction of steel for rails and tires made the use of larger boilers possible, and with their introduction came the successful use of the spark-consuming and arresting devices described. The railroad with which I am connected has had these appliances in use on a limited number of engines for the past two years, and in no case has a forest or other fire been set by them, and if kept in proper order I believe they are absolutely safe.

In conclusion, I wish to say that careful and intelligent manipulation of the fire by the fireman is imperative, and will do more to prevent the formation of smoke than any mechanical contrivances.

Upon solicitation the following letter on the same subject was received by the Department:

IMPORTANCE OF SPARK-ARRESTERS.

Chicago and Northwestern Railway Company,
Department of Motive Power and Machinery,
Chicago, October 27, 1886.

Hon. Norman J. Colman,
Commissioner of Agriculture.

Dear Sir: I herewith beg leave to submit the following in answer to your request in regard to the best appliances in use on locomotives on the railways of this country for the prevention of fires on the lines of such railways, the preservation of forests, and all vegetation contiguous to them. It is a subject that has engaged and is, I believe, engaging the attention of many of the practical and scientific men of the day. Perhaps the subject has not yet received the attention it deserves, but I believe there is a growing tendency, both by railway officials and those not connected with railways, to solve this question; and while I do not think we have attained perfection, and never may attain it, I do think great improvements have been made in this direction within the last few years. For many years the almost universal practice was to use what is called the "Diamond Stack," which is too generally known to need a description here. While this and its appliances may have been faulty in principle, or in some particulars, it has been considered the standard until within a few years, when to some extent it has been superseded by other appliances for arresting sparks, among which (and one that is meeting with the most favor) is what is known as the "Extended Front-end and Straight Stack." This device differs materially from the appliances used with the "Diamond Stack," both in construction and principle. With the "Diamond Stack" the practice usually has been to place the netting in the stack over a cast-iron cone or deflector, the point of discharge of the exhaust pipes from 8 to 12 inches above the lower row of tubes in the boiler, and between the top of the exhaust pipes and the bottom of the stack, an intermediate pipe made of a size to give the best results according to the varying conditions, and designated as an "extension pipe," "petticoat pipe," and by various other names, but all for the same purpose, although varying in construction, to equalize the draft and carry the cinders that would be drawn through the flues in a straight line to the point or center of the cone or deflector; here they would be turned downward again and broken up by contact with the cone or deflector, and either be burned in the bottom of the smoke-box or pass out through the netting above. This is but one of the many devices in use, varying in construction, but yet embodying the same general principles. With the "Extended Front-end" the principle is different in many particulars; the exhaust pipes are carried higher, the point of discharge being above the netting, creating what may be perhaps fitly called a vacuum draft, instead of a direct or more forced draft (as in the other devices named), thus admitting of a larger area of netting and equalizing the draft more perfectly than with the other arrangements, in which the point of discharge is below the netting and nearer the bottom of the boiler or flues. My experience has been that more complete combustion of smoke and gases is obtained by this device than by the "Diamond Stack" and the appliances used in connection with it. The question of brick arches, or deflectors as an aid to combustion, has also received a good deal of attention and discussion from many who have made careful experiments with them, but I believe there is a great difference of opinion in regard to their utility for that purpose. My own experience is, that I have got better results from their use as an aid to combustion, and also as a preventive of fire being thrown from the stacks of locomotives than without them. While no doubt a large percentage of the destruction of forests along the lines of railways may be attributable to fires originating from sparks from stacks and ash-pans of locomotives, yet it is also a question whether, owing to the imperfect combustion, a large percentage is due also to the escape of noxious vapors and gases from locomotives. At the time this may be an unseen factor, yet I believe it is a very potent one, and one, too, that can be overcome only by more perfect appliances for effecting that result. The practice now is, largely, to increase the dimensions of the cylinders of locomotives to the maximum which boilers with our present standard gauge of road can be made to supply. This forcing process I presume will prevail as long as coal can be furnished for fuel to locomotives as cheaply as it is at present on many of the large railroads of the country, and in view of the increased tonnage locomotives can haul under this system; for it is a process quite necessary in generating steam enough to supply cylinders, which are perhaps not always in proportion to the boiler-capacity, nor with the end in view of a more perfect combustion.

In regard to the best appliances to prevent the evils complained of, I have endeavored as far as possible to confine myself to my own experience in the matter. I do not think it is my province to commend any one or particular device for this purpose, nor do I think that any one can, in view of the fact that the service on the railways of this country and its conditions are so varied. The great difference in the quality of the coal used on the different roads, and many other factors, all combine to make it difficult to recommend any one device that would be applicable to all; while the same general principles might apply if modified to meet the requirements of different kinds of service and conditions. But from my own experience I believe that we are obtaining, and shall obtain, better results from the use of the "Extended Front-end," and its appliance, in the way of combustion and less liability to fire, than from the use of the "Diamond Stack" and its appliances. I believe also, if the importance of the matter should be properly presented to the managers of railways of this country, and a reasonable amount of discretion is allowed to officials in charge of the motive power of our railways to make a system of careful and intelligent experiments, the best results will be obtained.

Very truly yours,

G. W. TILTON,
Superintendent Motive Power and Machinery.

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DEPARTMENT OF AGRICULTURE.
FORESTRY DIVISION.
BULLETIN No. 2.

REPORT

ON THE

FOREST CONDITIONS OF THE ROCKY MOUNTAINS,

AND

OTHER PAPERS;

WITH A MAP SHOWING THE LOCATION OF FOREST AREAS ON THE ROCKY MOUNTAIN RANGE.

SECOND EDITION.

WASHINGTON:
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LETTER OF TRANSMITTAL.

U. S. DEPARTMENT OF AGRICULTURE,
FORESTRY DIVISION,
Washington, D. C., January 6, 1888.

SIR: I have the honor to submit for publication as a special bulletin, prepared under your instructions, a collection of reports illustrating the forest conditions of the Rocky Mountains, together with such information as may serve for a basis in formulating needed forest legislation with reference to the timber lands of the region which are still held in the hands of the General Government.

Respectfully,

B. E. FERNOW,
Chief of Forestry Division.

Hon. NORMAN J. COLMAN,
Commissioner.

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INTRODUCTORY.

The following report and papers are designed as a basis for an intelligent conception of the possibilities and requirements of legislative action on the part of the General Government in regard to some of its property. They will also, it is hoped, be welcome to the student of the climatic, floral, and economic conditions of the region to which they refer, and serve as a historic reference book in the times when the folly of present days will be judged by those who will suffer its consequences.

The pioneering days are rapidly disappearing before the energetic push and advancement of railroad building and settlements; and with the changed conditions of life, in communities instead of in isolated log huts, a change in the manner of life and its adjustment to the demands of civilized existence is called for.

The development of the Rocky Mountain region during the last seventeen years is indicated by the growth of its population. The population has increased from 263,236 in 1870 to 900,000 in 1886, while the assessed valuation, exclusive of mining property, has risen from $96,507,000 in 1870 to $330,000,000 in 1886. This growth has been obtained, no doubt, partly through the liberal policy which the Government has pursued in regard to railroad grants, to mineral claims, to land entries, etc.

Of the enormous amount of public lands given free or at nominal prices to settlers, miners, and to encourage development, amounting to about 630,000,000 acres, a proportionate share has fallen to the region in question. For educational purposes it received 22,963,403 acres or 34 per cent. of the total grant. Of the 50,000,000 acres or so of railroad grants, outside of the rights of way, 4,500,000 acres at least must be debited to the region for its 2,060 miles of land-grant roads. Under the desert-land act 1,193,548 acres were given up at $1 per acre. Under the timber-culture act, 389,991 acres have been entered in the region under consideration.

In addition to these grants a liberal use of the timber on the public domain, for all legitimate purposes which would aid the settler in building up and improving his settlement and the railroad companies in building their roads, has been permitted.

But whether the continuance of such lavish liberality after the pioneer existence is passed has not already been, and may not become still more in future, detrimental to the best interests of the region in question, as well as of the Pacific coast region, which should have been included in this discussion; whether a change from the present policy in regard to the remaining public domain would not better answer the purposes of the community at large—these questions now call for deliberate investigation.

That this need of a change of policy exists, especially in regard to the timber lands occupying the mountain regions of the Rocky Mountains and the Pacific slope, has been claimed and urged for many years by competent officers as well as by well-informed citizens.

The reasons brought forward for such a change in regard to the Government timber lands are partly of an organic, partly of a moral character.

In the present classification of lands, special regard to the existence of timber on the land is only given in California, Oregon, Nevada, and Washington Territory, where timber land not fit for cultivation may be sold in tracts of 160 acres, to any one person, at $2.50 per acre (act June 3, 1878), forbidding, however, the purchase for purposes of speculation, the land only to apply to the exclusive use and benefit of the purchaser, and the title not to inure to a third person. It is well known that this act has not been of much practical value, and does not furnish relief to the settlers for whom it was designed. Under this act nearly 1,000,000 (986,158) acres have been sold and are held by large corporations mostly.

The valuable timber lands in the Southern States have been mostly disposed of at private sales for $1.25 per acre, under the act of June 22, 1876, by which the public land policy, which had been stated to be that of holding the land for actual settlers, was repudiated. In Alabama this avowed policy sustained another blow from the act of March 3, 1883, by which the distinction of mineral lands was wiped out; and thus the door was opened for speculators, who have not failed to take advantage of the chance, and have bought many millions of acres of valuable timber for a small price.

In the Rocky Mountain States and Territories, as well as in all other parts of the United States, all bona fide residents are permitted (act June 3, 1878) to fell and remove for building, agriculture, mining, or other domestic purposes, timber or other trees on the public lands which are mineral and subject to mineral entry only, and on the land entered under homestead acts, and they are also allowed to clear for the purpose of cultivation and improvements only, not for sale, before the patent accrues to them, any timber on their entries.

In addition to the grants of right of way and the land grants of alternate sections under the general right of way act and other acts to aid in construction of railroads, the railroad companies are allowed "to take from the public lands adjacent to the line of said road the timber necessary for the construction thereof," this right to cease at the expiration of five years after location, and, of course, after construction.

This permission has in practice been construed by the railroad companies into a license to cut timber wherever, whenever, and for whatever purpose they saw fit, before and after construction.

That the timber on the public domain had a special value, and also that it needed, like all movable property, to be looked after and protected, was recognized by the act of March 2, 1831, under which, for the care and custody of the timber on the public domain, a system of agencies under the supervision of the Solicitor of the Treasury was established. When, in 1854, the management of the timber interest was transferred to the General Land Office, and the registers and receivers were expected to act as timber agents without additional pay, an exceedingly loose construction as to the right to take timber, and naturally a lax enforcement of any laws, prevailed until 1877. In fact, until 1876 the collection of stumpage, when found out, was the only penalty for timber stealing, and a regular revenue, payable quarterly at the discretion of the receivers, was attempted to be collected from the saw-mill men without any sanction of law. From the year 1872 until 1877 annual appropriations were made for this service, amounting in the aggregate to $48,000 ($45,624.76 expended).

In 1877 the Commissioner of the Land Office instituted a service of special agents, and in 1878 a special appropriation of $25,000 was made "to meet the expenses of suppressing depredations upon timber on the public lands." The system of special agents was gradually enlarged and the appropriations increased, with the results during the last seven years as exhibited in the table below.

Depredations on the public timber during seven years.

Year.	Estimated value of timber reported stolen.		Amounts actually recovered, partly by compromise.	Appropriations for protection service.	Agents employed.	
	Market.	Stumpage.			Number.	Months employed.
1881	$891, 888	$225, 472	$41, 680	$40, 000	17	(?)
1882	2, 044, 278	511, 069	77, 365	40, 000	31	(?)
1883	8, 144, 658	1, 709, 824	27, 741	75, 000	25 *13	12
1884	7, 289, 854	1, 093, 178	52, 108	75, 000	26 *44	12
1885	2, 862, 530	489, 255	49, 451	75, 000	23 *41	8
1886	9, 339, 679	1, 726, 516	101, 086	75, 000	21 *50	12
1887	6, 146, 935	1, 138, 320	128, 642	75, 000	26	12
Total	36, 719, 852	6, 893, 634	478, 073	455, 000	27	

* Actual number of agents employed for shorter periods.

With more and more urgency have the Commissioners of the Land Office, the officers to whose care, under the Secretary of State, this prop-

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NOTE.—During the thirty-three years from 1855 to 1888 the sums recovered from trespassers amounted in the aggregate to $491,172.

erty is intrusted, insisted that under existing laws and conditions not only is it impossible to protect the property of the people against theft and devastation, but the need of the settler and the requirements of the industrial pursuits being disregarded by the law, the users of timber are by necessity forced to become depredators if they wish to satisfy their needs. That such must be the case may be inferred from the fact that within the last seven years, since 1881, over $36,000,000 worth of timber has been reported as stolen, not to speak of the large amount of depredations which must have been left undiscovered.

While the Government might have donated this timber, or timber and land, to those who have needed it—although the need of home consumption has presumably had a less share in these spoils than the greed of lumbering monopolists—it must be a matter of shame and reproach to us to have in this manner allowed the spoliation of the public property; certainly a state of affairs, which allows such robbing of its partners from year to year, does not speak well for either the wisdom of the laws or the morality of the community.

In addition to these spoliations of its direct material value, the public timber domain has suffered untold damage by reckless, willful, or careless firing, and in every respect the management of this part of our national inheritance reflects discredit on our much-praised business capacity.

It has been claimed that the fault lies with the existing laws, and this charge has no doubt good foundation. The charity which the Government has extended, in allowing free use of its property under certain conditions, the settled community now would gladly exchange for a fair bargain, in which the consumer pays for what he uses, and gains a right as against a mere privilege.

Any one who will take the trouble to trace, year by year, the expressions in regard to this interest of the nation, in the reports of the Secretary of the Interior and the Commissioners of the Land Office, will be astounded that no hearing has been accorded to them which would lead to a proper management of this interest.

Recommendations for a change occur from year to year, dating back earlier than 1880, but they have become more and more urgent since then as the need has become more urgent. Extracts from the reports of the Commissioners of the Land Office will be found further on.

The Secretary of the Interior, in 1880, after devoting over six pages to the subject of forestry, says:

> I regret to say that in spite of the repeated recommendation of the passage of a law to facilitate the prevention of the wasteful devastation of the public timber lands, and to enable the Government to dispose of timber to settlers and miners, as well as for legitimate mercantile purposes under such regulations as would prevent the indiscriminate and permanent destruction of our forests, almost all the legislation that has been had upon this subject consisted in acts relieving those who had committed depredations in the past of their responsibility and protecting them against the legal consequences of their trespasses, etc.

And Secretary Lamar, in 1885, repeating his recommendations in 1886 and 1887:

> The subject of the preservation of timber on the Government lands has been suggested to Congress repeatedly in the reports of my predecessors. Perhaps its frequent repetition has rendered it commonplace, until it has come to be recognized as a part of routine report. Its importance justifies its repetition. That the timber is rapidly disappearing is an indisputable fact. Much is wasted and destroyed. Its effect on rain-falls, the flow of our rivers, and the healthful character of climate are subjects worthy of consideration. Its importance and necessity for agricultural, domestic, and mechanical uses requires no portrayal. Good government, while not forgetful of the present, should use some care for the future. Both on account of its present importance and its future necessity, this subject is worthy of your thought.

And further, speaking of the timber act of 1878:

> Its enactment was suggested, doubtless, by the fact that settters in a new country, surrounded by woodland, could not and would not suffer in a rigorous climate for want of fuel and shelter; that the necessary industries of a frontier would not submit to the pinchings of a famine in the midst of abundance. But while it was necessary to recognize the inevitable, the recognition was not properly guarded, and waste and greedy speculation seems to have resulted from the law.
>
> Any timber for the uses named in the statute may be cut, under its provisions, by any resident of the Territory on any mineral lands of the Government, in the Territory of his residence, without compensation. Individual avarice and corporate greed, thus invited, with hasty eagerness, vie in accepting the bounty, and unless checked by wholesome modifications of the law, will soon cause all the mineral lands to be stripped of their forests. Railroads pass through many of the Territories; along their routes wealthy companies have been organized, mills erected, and the most valuable timber accessible is being rapidly cut off. That which is "every one's property is no one's care," and waste and extravagance are the natural consequence of negligent legislation.

The last report of the Commissioner of the Land Office (1887) contains a chapter illustrative of the manner in which a small minority has been for a long time defrauding the nation unchecked. Any citizen who feels himself a part of the great government "of the people, for the people, by the people" will do well to ponder over these pages of disgrace.

Such is the moral aspect of our present conditions in regard to the land laws and to the reasons for a change in our forest policy. The organic reasons are those which compel us to consider the forest cover of the mountains as of more importance than merely to supply material for the present.

Under existing conditions not only is it made difficult for the resident population to supply itself with the needed lumber in an honest way, but the danger of doing so in contravention of the law entails an enormous needless waste. Acres of timber are felled in anticipation of possible use, and rot on the ground, because their haulage may become too risky, or the depredator finds it difficult to dispose of the property, and so it is left to furnish food to the ever-recurring annual fires, which destroy also not acres but miles of standing timber, and no legal disposition of the burnt timber may be made.

That those who may cut timber legally on mineral lands, or homesteads, or timber entries on the Pacific slope have no interest except to satisfy a present momentary need, and clear the land regardless of any consequences to future supply, or proper management, or forest conditions, utilizing only whatever part of the trees they may readily use or require, leaving the balance in the most wasteful manner on the ground, is attested by those acquainted with the manner of timber-cutting in those regions. Any sign of intelligent and systematic management which would insure a full utilization and continuity of the same is, of course, absent and is not encouraged by present regulations under the existing laws, and local supplies are waning in many parts. While in view of the needs of local supply for mining operations, especially in mines yielding low-grade ores, which can not bear the burden of heavy charges for the importation of their timbering, this is an undesirable prospect, a much more serious danger is threatening the community at large in and around these mountain regions.

The climate, as will be seen from the paper of Mr. Parsons included in this report, is, in many parts of the region, not favorable to tree growth; at least not to the germination of seeds of coniferous trees, which form there the natural growth, except under specially favorable conditions, while broad-leaved trees of economic importance are not naturally found in the region, or only in small quantity. These unfavorable conditions are, by the act of man, made still more unfavorable. The wholesale clearing which is practiced lays bare the thin soil to the influence of drying sun and wind; fires that sweep over the ground without hindrance destroy the thin mold and whatever seedlings may have been on it, and thus natural recuperation of the forest is made impossible, and any attempt at artificial reforesting is almost precluded. Barrenness and desolation is, as a rule, the result, except that in more favorable situations the quaking aspen, of little economic use, may find a foothold, covering the nakedness of which nature has become ashamed.

If, in view of so much graver consequences, it were permissible to allude to it, I would impress upon those who take a delight and a pride in the charms with which nature has endowed our country, vying with the finest scenery of Europe, that the beauty of the once verdant mountain sides is being ruthlessly and needlessly destroyed, and with such general equanimity is this devastation considered that we may soon substitute in our dictionaries the word "Americanism" for "vandalism."

What the graver consequences are can be readily understood by those who have studied the history of deforestation and forest devastation in southern France, Switzerland, Spain, Italy, and those far eastern countries which compare somewhat in climatic aspects with the region in question.

Not only is the forest cover of the mountain crests destroyed when it might have yielded continuous supplies, but at the same time agriculture in the valleys below is first endangered and then made impossible.

In a region which, like most of the plains of Idaho, Montana, Wyoming, Colorado, Utah, New Mexico, Arizona, and southern California, requires for agricultural purposes the aid of irrigation, regularity of water-supplies is all-important. This is being tampered with when the ground is laid bare on the mountain sides, allowing the rains to run off as from a roof and permitting the snows to melt and their waters to pour down in torrents at a time when more than enough water is on hand and the husbanding of the supplies for a later season is highly desirable.

Other consequences, such as an increase of snow-slides and land-slides and the washing of débris into the valley have begun to make themselves felt and it can only be a question of time when we must reach such a state of things as was brought upon the mountain districts of France, Switzerland, and the Tyrol, and which is too well-known to be rehearsed again. I will only mention that after entire communities had been impoverished by the action of torrents due to deforestation the Governments found it necessary to interfere, or rather, interference coming too late, to assume or aid in the work of reforestation. Thus in France it was found that 783,000 acres needed to be restocked for reasons of public utility, besides the securing of 1,900 miles of torrents. One hundred and three thousand one hundred and thirty-eight acres of mountain land are reported already as put in condition by the Government at a cost of $4,365,750, outside of the cost of expropriations, etc. To this must be added $1,116,643, which have been given to communities and private owners in aid of similar works, and a further expenditure of round $34,000,000 is expected to be necessary. Altogether it is estimated that $30,000,000 have been expended to correct the evils brought on by foolish disregard of nature's laws. For the year 1887 the appropriation for these purposes amounts to $794,000, the total appropriation for the forest department of France being in round numbers $5,000,000.

The public land commission in 1883, recommending necessary changes in existing land laws, says: "The timber lands should be sold. Will not private ownership, self-interest, best protect this class of lands?"

If the history of the countries just cited, if the forest lands in the older settled parts of our own country, have not shown that this is a fallacy, we may never expect to learn from experience.

While the existing system of espionage and police may be "unpopular and un-American," as it undoubtedly is, it exists, not because there is no other choice than sale, but because there are no adequate provisions made to satisfy the requirements of lumber for actual and commercial use, thus forcing the population to depredations. Settlers and consumers of wood can not be expected to go to the woods and cut their sticks when wanted, as in the pioneer days. They must have an opportunity to supply their wants in a business manner, as they do in all other needs of civilized life, through the agency of a middle-man—in this case the lumberman or the saw-mill man—nor, with the absence of stability in our population, can more than a temporary or an ephemeral interest attach to forest property for the individual.

It is not the forest that is valuable and would appear worth his protection to the individual, but the timber which the forest yields. As soon as that is gone the value and the interest is gone for the individual. The interest which the community has in the forest is transcendant. The continuation, reproduction, and protection of the forest cover is of importance to the continued welfare of the community, especially in the mountain forests, and they will therefore be in safer hands with the community at large, with the state.

Let it not be overlooked that the state is not only the representative of communal interests as against individual interests, but also of future interests as against the present; that the forest is a kind of trust, of which the usufruct belongs to the present, and that to draw upon its capital is a perversion of the trust and can only be excused by direst necessity. Every other civilized country has found out after severe punishment that private interest is not sufficient to protect this class of lands; that state ownership or, what is more objectionable and less effective, state supervision of private forest lands, is indispensable in those regions where the forest subserves other functions than that of mere material supply.

Whether or not interference of the state in the management of one of the most potent factors of national welfare is un-American has been fully discussed in the paper contributed by Prof. E. J. James, well known as a writer on economic subjects.

The report of Colonel Ensign, the facts for which were gathered under many difficulties for lack of more liberal funds than could be allowed for this work, will present a clear and tolerably exhaustive picture of the present conditions (1887) of the region in its economic development and other aspects, so far as they bear upon the consideration of our question and of the forest areas as distributed through its different parts.

It was impossible to include in this investigation the Territory of Utah, and although the writer of this, at his own expense, visited the Territory and obtained considerable information which would show that, if anything, the forest interests of Utah are in a more precarious condition than those of the other parts of the region, this information was not deemed complete enough to appear as a separate chapter. A short résumé, however, has been appended to the report of Colonel Ensign.

The map accompanying this report was compiled from the returns which appear under the description of forest conditions by counties. It of course makes no pretense at exactness as to boundaries, but simply gives to the eye an idea of the relative position of wooded areas and of the principal irrigation ditches.

The question of what constitutes timber land is a perplexing one. As one or other view predominates, it denotes land stocked with trees ready for the saw-mill or merely land upon which there is a wood growth. If to "what is" we add the conception of "what ought to be," timber land would include also, in a mountainous region at least, all that treeless area which, not fit for agriculture or not needed in the development of mines, etc., can and should bear a tree growth and produce a timber crop.

In this connection the report of Mr. Abbot Kinney on the forest condition of the southern counties of California will be read with interest, showing that the timber lands in which the state should be concerned do not always contain "timber" of the kind in which the lumberman or other private owner would interest himself. For the preservation of favorable hydrologic and agricultural conditions even care of the "chaparral" may be of service.

To the student of the forest botany of the region the careful compilation by Mr. George B. Sudworth, of the division, will be welcome. The main effort has been to so arrange and describe all the woody plants of the region that the layman may be enabled, without much unnecessary technical terminology, to get acquainted with them; but at the same time the scientific botanist will find much aid in such a compilation, for which all authorities have been carefully consulted and, after due sifting, a truthful statement of facts attempted.

As it is the object of this bulletin to aid in forming a basis for intelligent forestry legislation, it seemed desirable to note what action had been attempted in the national legislature looking toward a better administration of the timber lands of the nation.

Mr. Egleston, of the division, has, for this purpose, compiled a complete reference table to this kind of legislation, from which it appears that attempts to effect a change have not been unfrequent, although unsuccessful. No doubt the more pressing interests of the day have excluded from the halls of Congress proper consideration of the vital interests of the future.

Since there does exist in the region a Government reserve of timbered country—though not by any means created with a view to the needs of forestry—it was desirable to give special information as to its conditions and its further needs at the hand of Government. No more competent writer for this task could have been found than Mr. Arnold Hague, for several years geologist-in-charge of the National Park; a man thoroughly acquainted with the ground, of broad views, and alive to the important interests depending on such timber reservations. The letter which he kindly consented to contribute, will, it is hoped, stir up an interest in those who, while in sympathy with the idea of the National Park, can not rise to the broader conception of national forestry.

A chapter on snow-slides, prepared by the writer, will give an imperfect intimation of what direct dangers may be expected from forest devastation in the mountains, and how to meet them.

The concluding pages, kindly contributed by Mr. Parsons, will be read with interest by those who, in the plains of the region in question, have begun to ameliorate their climatic conditions by the planting of trees and groves.

Fully aware that defects in a report like the following must become apparent to any one who peruses it with interest and finds one or the other important question imperfectly answered or altogether overlooked —defects which are due to many different causes, too many to recount— I still hope that they will not prove such as to overshadow the value of the work as a whole for the purpose for which it has been done. Love and zeal, at least, have been brought by all the contributors to their work in behalf of the great national interest which is connected with the "backbone" of this continent.

B. E. FERNOW.

EXTRACTS FROM REPORTS OF THE COMMISSIONERS OF THE LAND OFFICE.

Commissioner Williamson, in his reports, deals at length and in detail with the depredations, the deficiency of funds to counteract them, the feeling of the law-abiding citizens in regard to them, and proposed changes.

Commissioner McFarland says, in 1881:

> The existing provisions of law permitting citizens to fell and remove timber on the public lands for mining and domestic purposes, as found in act of June 3, 1878, are, in my opinion, very defective. The only lands from which such cutting is authorized are the mineral lands.
>
> (1) The mineral lands are to a great extent undefined and necessarily must so remain.
>
> (2) Large quantities of timber are absolutely necessary for the development of mines, while the said act authorizes the cutting thereon of the timber for other purposes. The purchaser of a mining claim has as much (if not a greater) need for the timber thereon as the agriculturist; and the transportation of timber to the mines from a distance is very expensive.
>
> (3) The law furnishes no relief to such as reside at a distance from such lands. The situation is practically this: The settlers on lands devoid of timber need timber for fuel, building, etc. Very frequently they can not get it, except from the public lands. If they can not get it legally still they will take it, and when taken solely for said purposes it is under circumstances which largely mitigate the technical legal offense.
>
> While parties who steal the public timber for speculation and profit deserve severe punishment, those who use it solely for home purposes, under the imperative necessities above mentioned, should have their privileges accurately and reasonably defined. I deem the enactment of some law which will accomplish this end to be very desirable and in the public interest.

In 1882:

> Proceedings for the protection of the public timber are now had under several different statutes, some of a general and others of a more local character. Much embarrassment grows out of this diverse legislation, portions of which are also conflicting.
>
> It is my opinion that a general law should be enacted clearly defining the rights of citizens to take timber from the public lands for prescribed purposes, and providing penalties for unlawful cutting, removal, destruction, or waste.
>
> Of the various classes of cases of trespass with which this office has to deal, the most numerous are those committed under cover of homestead entries, fraudulently made for the purpose of securing the timber on the land. This class of entries does not seem confined to any one locality, but the fraud is perpetrated wherever there are public timber lands subject to entry under the homestead laws.

In 1883:

The present increasing value of timber is an inducement to individuals and companies to make large investments with a view to the control of the timber product and the further enhancement of prices resulting from such control.

It would, perhaps, be of little moment how soon the public title to lands should pass to private holders, since that is the ultimate purpose of the laws, if the further purpose of the laws that public lands should in the original instance be widely distributed among the people could be secured.

Public notices relative to forest fires have been prepared to be posted, have been of beneficial effect, but no funds are on hand to do enough in this direction.

In regard to the timber and stone act of 1878, he says:

The restrictions and limitations are flagrantly violated.

Evidence is cumulative that the act is made use of by corporations and wealthy individual operators to secure fraudulently, for the purpose of manufacturing into lumber or to hold for speculation, the accessible forests yet remaining in the States and Territories, thus to be lost to those who would enter and make use of them.

Fraudulent removal of timber on mineral lands, under cover of this act, is also reported:

Information is in my possession that much of the most valuable timber is being taken up by home and foreign companies and capitalists through the medium of entries made by persons hired for that purpose. I have found it necessary to suspend all entries of this class. * * *

In 1884, in regard to the same act:

The developments of the past year emphasize the foregoing statements relative to the prevalently illegal character of this class of entries. The result of the operation of the act is the transfer of the title of the United States to timber lands practically in bulk to a few large operators.

The preventive measures at the command of this office have proven wholly inadequate to counteract this result.

Public interest would be served by its repeal.

Speaking of the necessity of some measure by which natural forests may be preserved at the headwaters of important rivers, the Commissioner says:

The importance of the subject can not perhaps be overestimated, and it is apparent to me that if anything is to be done in this direction it should be done quickly. The forest areas of the country are rapidly diminishing, and the timbered lands of the United States will, under existing laws, soon be exhausted. To a great extent such lands are now appropriated by pre-emption and commuted homestead entries, made without settlement except that of lumber camps, and without improvement except the cutting and removal of the timber for commercial purposes. The United States receives only the minimum agricultural price of the land, irrespective of its real value, which is usually largely in excess of the Government price.

The low price at which such lands are now obtained stimulates fraud in acquiring titles and holdings for future speculative purposes, while as soon as reduced to private ownership such lands have their proper market value, and the cost of timber products to consumers is naturally predicated upon that value and not upon the Government price at which the lands were primarily obtained.

Commissioner Sparks expresses himself as follows, in 1885:

Depredations upon the public timber are universal, flagrant, and limitless. Whole ranges of townships covered with pine timber, the forests at headwaters of streams, and timber land along water-courses and railroad lines have been cut over by lumber companies, under pretense of titles derived through pre-emption and homestead entries made by their employés and afterward assigned to the companies. Steam saw-mills are established promiscuously on public lands for the manufacture of lumber procured from the public domain by miscellaneous trespassers. Large operators employ hundreds, and in some cases thousands, of men cutting Government timber and sawing it up into lumber and shingles, which, when needed and purchased by local citizens, can only be obtained by them at prices governed by the market value of timber brought over expensive transportation routes from points of legitimate supply.

Under cover of the privilege of obtaining timber and other material for the construction of "right-of-way" and land-grant railroads, large quantities of timber have been cut and removed for export and sale. Immense damage is also inflicted by the destruction of small growing trees and the spread of forest fires, resulting from a failure to clear up the land and dispose of the brush from felled trees, even in the cases of authorized cutting.

And in regard to the timber-land act of June 3, 1878:

It has operated simply to promote the premature destruction of forests, the shipment of their products out of the country, or for holding lands and the lumber needed by the citizens at the speculative prices demanded by foreign and domestic corporations acquiring a monopoly of the timber lands of the Government at nominal rates through easy evasion of the terms of the law.

Why, as a mere business proposition, timber lands worth at lowest averages from $10 to $25 per acre for the standing trees or, according to accessibility and class and quality of timber, worth $25 to $100 per acre should be sold by the Government for $2.50 per acre it is not easy to perceive.

The evils developed in its practical operation are inherent in the system and can be cured only by a repeal of the law by which they are propagated.

And, further, in enlarging upon the importance of forest preservation in the mountains, he says:

The Government is now expending large sums of money in attempts to substitute by artificial means the regulation of the flow of the Mississippi River which nature had provided in the dense woods originally surrounding the sources of its numerous tributaries.

That wise and speedy measures should be adopted for the preservation of forests on the public domain is in my opinion an incontrovertible proposition. To this end I recommend the immediate withdrawal from appropriation, sale, or disposal of all the public forests and of lands valuable chiefly for timber, subject to future legislation for the permanent reservation of designated areas and a more economically-governed disposal of such timber lands or timber as it may not be necessary indefinitely to reserve.

In 1886:

Depredations upon the public timber by powerful corporations, wealthy mill-men, lumber companies, and unscrupulous monopolists are still being committed to an alarming extent and to the great detriment of the public at large.

An immense pressure is brought to bear upon the legislative and executive branches of the Government to the end of securing immunity for past and unlimited privileges for future spoliations of public timber lands, all ostensibly urged in the interest of bona fide "agriculturists" or "miners," but notoriously in fact to forward gigantic schemes of speculation and monopoly in the remaining forests of the United States.

Replying to a request for a change of construction, so as to permit mill-owners to cut timber for their mills on land that might be mineral, the Commissioner writes:

The act itself is injudicious and entirely too broad, and its repeal or modification has been recommended by you (the Secretary) for the reason that its provisions ignore the importance of the preservation of the timber, and invite, in a measure, great waste and greedy speculation by individuals and corporations. It is impolitic and unjust in not preserving timber for the use of future settlers and inhabitants, and permitting it to be taken in large quantities without consideration and proper restrictions. It, however, is still the law, and so long as it remains on the statute book it can be enforced.

The act of June 3, 1878, gives the timber to the miner and settler, but if the saw-mill men can come in and cut and sell it, they, and not the settlers, will get the benefit of the timber. The interest of the settlers and lumbermen in this matter are not identical.

But a later circular (August 5, 1886) permits the sale of timber or lumber to bona fide residents for the legitimate use of the purchasers in compliance with the provisions of the act, which means for actual personal consumption. In this circular the right of existence of saw-mills using timber cut on Government land is recognized, and while it is imposed upon the saw-mill men to keep such records as will show where the timber they manufacture comes from, and to obtain an agreement from the purchaser that he will use the timber legitimately according to the spirit of the act, the door is opened to circumvent the law.

It is also stated that "there exists no authority of law for granting the privilege of cutting timber on the public lands and paying stumpage therefor;" that "there is no authority to dispose of burned timber separately from the land."

In 1887:

Such a record of crime as that shown by investigations made by special agents during the last two years is rarely to be found. Bold, reckless, and gigantic schemes to rob the Government of its lands have been discovered and exposed in every State and Territory containing public lands.

The unavoidable continuance, on account of the early exhaustion of the appropriation to pay witnesses in United States courts, of the important cases against the Sierra Lumber Company, in California, involving over $2,000,000, and in which two special agents of this office devoted nearly their entire time for a year in securing evidence and preparing for a successful prosecution, and of the cases against the Montana Improvement Company and Northern Pacific Railroad Company, in Montana and Idaho Territories, involving an equal, if not greater, amount, is greatly to be regretted. The delay in these cases can not fail to be exceedingly detrimental to the public interests. The Government, so far as the office is concerned, was fully prepared, and had every reason to expect that had said cases come to trial judgments would have been secured for nearly the entire amounts sued for.

During the delay in the prosecution of the above and other important pending cases the defendants are by no means idle. They not only continue their unlawful depredations on public timber in defiance of all efforts of this office to prevent that course, but they avail themselves of every such opportunity to destroy the evidence of their past transgressions and to nullify the efforts of this office.

By the time these cases can again be brought to trial many of the witnesses will have disappeared and much of the evidence depended upon by the Government will have been destroyed, necessitating a re-investigation and the securing of additional evidence in nearly every case, thereby duplicating the expenses of the special agents in preparing the cases for trial, exhausting the appropriation, and rendering it impossible for this office to cause the investigation of the many new and flagrant cases of trespass which are brought to its attention. The appropriation for this branch of the public service is *altogether inadequate for the purpose.*

The wholesale destruction of public timber on odd sections of public lands within the granted limits of unconstructed railroads, or of roads which failed to comply with the provisions of their grants, continues to an alarming extent. The delay of Congress in declaring the forfeiture of said grants is, in this particular alone, of great detriment to the public interests. Irresponsible parties are rapidly denuding such lands of their valuable timber, rendering the lands, in many instances, barren wastes and utterly worthless.

To secure proper enforcement of the laws and punish willful and persistent violators a force of at least fifty special timber agents, at an annual expense of $150,000, ought to be employed. I have, however, estimated for $125,000 as a minimum, below which a reasonable efficiency in the service can not be obtained. Vastly more can be accomplished in one year with a sufficient appropriation than can be accomplished in several years with smaller annual appropriations aggregating a larger sum.

The area of timbered lands in the United States is disappearing at a ratio that excites grave apprehension, while timbered agricultural lands in the public States and Territories generally may be regarded as practically exhausted. The necessity for clearing land of its timber preliminary to making a farm is exceptional. It is want of timber and not its surplusage that afflicts settlers on the public domain. The struggle to accumulate great private fortunes from the forests of the country has reduced forest areas to a minimum. What is left at the heads of rivers and streams and on mountain sides should be preserved as of infinite importance and value for climatic effect, the natural regulation of the flow of waters, and to prevent the relapse of large agricultural districts to a desert condition.

When timber had to be cut and burned as a necessity in clearing land for cultivation there was no cause for increasing the price of land because there was timber upon it. This is not the present situation. The remaining timber lands, as a rule, are worth little or nothing except for the timber, and their value for timber is being rapidly enhanced as transportation facilities increase and timber areas decrease.

The appropriation of $75,000 for the prevention of depredations on the public timber is TOTALLY INADEQUATE. The vast fields to be covered, stretching from Florida to Alaska, can not be supervised by twenty-five special agents, nor can the determined efforts of timber depredators, many of them corporations with millions of dollars at their command, to despoil the forests of the country, be met by puny attempts to check their unlawful and disastrous acts. The service is more than self-supporting, and draws no money from the Treasury that is not more than returned to it by fines and recoveries. It is no part of an intelligent or defensible policy to make timber depredations a source of revenue. The object to be attained is to save the forest lands from unlawful destruction, and if this can be accomplished by appropriating the whole of the receipts derived from trespass prosecutions there should be no hesitancy in allowing the administrative department the aid, at least, of the amount it recovers. My estimate for the next fiscal year is $100,000 for this purpose, a modicum only, I must say, of the amount that could be beneficially and profitably expended.

Three years ago my predecessor recommended an appropriation of $400,000 to protect the public lands from unlawful and fraudulent appropriation. Since that period the need of such protection has increased with the intensified demand for public land holdings for monopolistic and speculative purposes. Yet Congress at the last session allowed but one-fourth of the sum regarded as requisite under the preceding administration of the Government.

Both Congress and the Executive, not less than political parties, annually assert an intention that the public lands shall be preserved for actual settlement. No public demand is greater than that land monopoly shall not be fostered by the Government. Yet at the vital point where these words are to be put into action, Congress fails to place in the hands of the executive branch the means to redeem these public promises and to prevent the indiscriminate waste and misappropriation which has for years dishonored the public-land system, and through which great areas of lands needed for actual settlement pass into the hands of speculators, syndicates, and corporations.

THE GOVERNMENT IN ITS RELATION TO THE FORESTS.

By E. J. JAMES, PH. D.,

Professor of Public Finance and Administration in the University of Pennsylvania.

The forests of any large country bear a peculiar relation to national prosperity. They not only constitute a large proportion of the natural wealth of a nation, but they form the indispensable basis of a flourishing agricultural, manufacturing, and commercial industry. They are, moreover, one of the most important elements in determining the climatic conditions of any given region and, through these, the distribution of population, of industrial pursuits, and of disease and health.

According to the census report of 1880 the value of the forest crop of the United States for that year exceeded $700,000,000. To obtain an adequate idea of the relative importance of this product it will only be necessary to institute a brief comparison with other branches of industry or wealth. The value of the forest products was equal to one-third of that of all farm products whatsoever sold, consumed, or on hand in the year 1879. It exceeded by over $100,000,000 the total assessed value of all the farming property in the six New England States, and by a somewhat smaller figure that of the farms of Virginia, North and South Carolina, Georgia, Alabama, and Mississippi. It would have purchased, at its assessed valuation for the purpose of taxation, the entire property, personal and real, of all the citizens of the States of Vermont, Delaware, Florida, Arkansas, Nebraska, Colorado, Nevada, and Oregon, and of all the Territories besides, and still have left a balance nearly equal to the same kind of property rated in the District of Columbia.

If to the value of the total output of all our veins of gold, silver, coal, iron, copper, lead, and zinc were added the value of the stone quarries and petroleum obtained, and this sum were increased by the estimated value of all the steam-boats, sailing vessels, canal-boats, flatboats and barges plying in American waters and belonging to citizens of the United States, it would still be less than the value of the forest crop by a sum sufficient to purchase at cost of construction all the canals, buy up at par all the stock of the telegraph companies, pay their bonded debts, and construct and equip all the telephone lines in the United

States. This sum of $700,000,000 exceeds the gross income of all the railroad and transportation companies in the United States, and, if we leave out New York and Pennsylvania, it would suffice to pay the public indebtedness of all the other States in the Union, including that of all the counties, townships, school districts, and cities within those States. In a word, we have to do here with an interest ranking third in the line of importance, even from the mere view of dollars and cents, counting manufacturing of all kinds first and agriculture second.

If forests, therefore, were of no more consequence than as the source of the wealth which their annual yield represents, they would be worthy of special attention and care on the part of every community which would be considered thrifty and far-sighted.

From the very inception of government on this continent down to the present time our towns, counties, cities, States, and, since its establishment, the National Government, have devoted much attention and put forth great efforts in various forms to promote the development of agricultural and manufacturing industry.

By offering lands on easy terms, by giving premiums for excellence of products, by encouraging the importation of improved breeds of live stock, by promoting the use of fertilizers, by free distribution of seed, by the establishment of experimental stations, of model farms, of agricultural schools, and of fairs, by exempting land from taxation for a certain length of time, and by many other means, the endeavor has been made to enlarge and improve agriculture.

By the establishment of a so-called protective tariff, by bounties, by exemption from taxation, by direct grants from the public treasury or by subscriptions of private parties, by a system of patent rights, by premiums, by expositions and exhibitions, and by the establishment of technical schools and similar means in many directions, we have labored to diversify and enlarge our manufacturing industry.

More especially have we tried to secure that fundamental condition of a highly civilized state, general and rapid means of transportation and communication. We have expended untold sums in the improvement of our highways and water-ways. Country roads, turnpikes of many different kinds, railroads, canals, we have practically constructed at the expense of the public Treasury. We have laid out large sums in the improvement of our rivers and harbors in order to faciliate our commerce. We have established and maintained at a large cost to the general Treasury a Federal post-office, which performs many of the functions of an express company.

But not only for transportation, agriculture, and manufacturing has the Government actively engaged in a promoting and fostering way. It has passed laws for the preservation and increase of various forms of our natural wealth. Most, if not all, of the States have undertaken to protect game and fish from the ravages of private individuals. They have enacted laws which have for their object the limitation of what was until recently an unrestricted right to kill as much game and to catch as many fish as any one could. The General Government has gone even further; it investigates the habits and history of the clam, the oyster, and the lobster, with the purpose of supplying information which will promote their successful and profitable cultivation. It has undertaken the business of stocking the rivers and lakes, even the shore waters of the ocean, with fish. By these and other means it seeks to preserve the sources of natural wealth from the devastations of selfish persons or to render them more valuable.

Our forests, on the other hand, from which we are drawing a larger amount in natural wealth than from any other source of supply, or indeed from all other sources together, we have so far done practically nothing either to protect or to cultivate. While this seems strange when we contemplate the forests, as we have done, merely as a source of raw material for our mechanical industries, it will seem the more remarkable when we consider how much more important the forests are on other and widely different accounts. Although they are the chief source from which we draw all our building materials, yet even if they should cease to yield sufficient to satisfy our wants in this direction, we could perhaps secure enough for this purpose for generations to come from the untold and untouched wealth of other countries, though at a vastly increased cost. We would resort, morever, in the face of a growing scarcity of timber, to other materials for our building, such as brick, stone, iron, and other metals. The value of the product of lumber was, for the census year, $233,268,000. This would be transferred, of course, to foreign countries, if the supply of lumber should give out in this country, but it might at least be possible to get as much lumber as we desired from outside sources by restricting our demands within narrow bounds.

The fuel supply of the country would, of course, be very much diminished if our forests were cut off and none others should take their place. In the census year, three-fifths of the people of the United States used wood as the ordinary domestic fuel, and the total value of wood used for fuel purposes amounted to nearly $325,000,000. At the same time, if wood should get scarce other material could be found to take its place as fuel. Coal and peat, natural gas, petroleum, and many other and perhaps some now unknown substances, might be substituted in place of the forest products for fuel.

Other articles for which wood is in demand, among which as most important may be mentioned fence posts and fencing material, handles, wheel-stock, wood pulp, baskets, boxes, etc., might all be supplied by other material, though at a considerable sacrifice in cheapness and, in some cases, convenience.

It is to be said, however, in this connection, that in spite of the inventions or application of substitutes for wood, the demand for the latter shows no tendency to decrease in an advancing community, since the growth of population and the ever-multiplying wants of an expanding industry more than keep pace with the substitution of other materials, and a rising price of wood is likely to be the result.

But forests occupy an entirely different position from all other forms of natural wealth, and a far more fundamental one. They determine, to a very large extent, climatic and hygienic conditions, and, through these, the prosperity of industry and the distribution of disease and health. The functions of forests in modifying climate and soil are so fully and ably presented in the various reports and bulletins of the Department of Agriculture, and in the proceedings of the various Forestry Associations, that the merest summary of the important facts will suffice for our present purpose.

Whether the presence of forests actually increases the total amount of rain-fall within any great region may still be a subject for dispute, but all authorities agree that forests produce a much more equable distribution of moisture throughout the year than exists where they are not found. In a treeless district, particularly if it be hilly, the rain glides off into the rivulets and into the rivers, scarcely moistening the ground below its surface. The burning rays of the sun, or the sweeping blasts of air, cause the rapid evaporation of what may remain here and there on the surface or may have penetrated a little way into the soil. A few hours after the rain there are almost no signs that rain has fallen at all. On the contrary, where there are forests the interlaced roots of the trees and the mass of leaves above them act as a sponge, which absorbs the water and holds it long enough to enable it to perform its service of quickening animal and vegetable life. The water oozes and trickles down through this spongy substance, and flows slowly away to feed the springs and streams. The modifying action of great forests on the distribution of moisture is both direct on the immediate region lying about them, and indirect on distant localities, owing to their influence on the character of the streams and rivers which drain their areas.

Where streams are not thus protected and modified at their sources by forests they may become the cause of almost as much injury as benefit. Owing to the fact that the water flows off so rapidly, the streams become at one time raging torrents, sweeping everything before them and inflicting an amount of damage which it requires much of the time elapsing between floods to make good, while at another they dwindle into insignificance, scarcely furnishing water enough for the flocks and herds along their banks. Where the forests have been cleared from the sources and banks of historic rivers the result has been an entire change in the character of the streams. The history of the Rhine, Rhone and Danube, in this respect, is full of instruction for us, and if alternating periods of drought and disastrous floods can not always be directly traced to the removal of the forests, their aggravation and frequency has been shown, even in this country, to be due to such removal.

This influence of forests on the character of our streams is a much more important subject than it seems to a careless observer. It affects navigation, and through that the whole transportation system of the country. A river which is navigable only at high water, or for a part of the season, is of little value as a channel of commerce, and can scarcely be considered an active competitor with such an agency as the railroad. And yet to such a condition are many of our great streams being brought, and we are now called upon to spend large sums of money, on the one hand in dredging and cutting in order to utilize a decreasing amount of water in the dry season, and, on the other, in building dykes and embankments against ever-increasing floods from the melting snows of spring-time or as the effect of protracted rains.

The character of the streams has an important if not a controlling influence upon our manufactures. A system of factories and mills, which would spring up spontaneously along a water-course regularly and equally supplied with water, is rendered impossible if this stream becomes a mountain torrent during one quarter of the year, and an all but dry bed during another, even if in the two cases the same quantity of water falls during the year and flows off through this channel in the course of a twelvemonth. Such a state of things necessitates a resort to more expensive means of water supply, or to auxiliary power of another kind, which again means increased cost of production and a rise in the cost of living for every member of society.

Irregularity of streams also affects agriculture, and not only indirectly, through the industries above-mentioned, but directly as well. The decreased volume of water during the period when the least rain falls diminishes the humidity of the atmosphere and affects powerfully the quality and variety of crops which may be raised, while the increased volume at high water cuts into and carries away enormous quantities of the soil from the farms lying along the banks of the streams, even when it does not by its overflow spread ruin and devastation through the adjacent valleys.

A striking illustration of the extent to which a stream may be changed by the deforesting of its headwaters and shores is afforded by the river Schuylkill, from which Philadelphia draws its water supply. The current has become for a large part of the year so shallow and sluggish that it is no longer able to rid itself, as it once did with ease, of the impurities which are poured into it, and the quality of the water is deteriorating at a more rapid rate than the stream of impurity is increasing. This result can be due only to a change in the character of the stream itself.

The fundamental importance of forests is, if possible, still more evident in mountainous and hilly districts. Their existence in such situations is the absolutely essential condition, we will not say of obtaining the necessary rain-fall, or preserving the necessary moisture, but even of maintaining the soil itself. Without forests a soil can not be made, or preserved, on our mountain-sides. The action of frost and of rain easily sweeps away every vestige of soil and leaves only the bare rocks as the basis of agriculture and the sources of streams. The soil thus carried away chokes up the streams and finishes the work of destroying their navigable character, which was so surely begun when the disappearance of the forests changed their broad and equable currents into mountain torrents.

Forests, moreover, have a powerful influence upon the sanitary conditions of life, owing partly to their effect on temperature and moisture, and partly to their effect on the purity of the atmosphere. Careful observations have proved that if the moisture of the atmosphere rises above or falls below a given degree certain diseases become more prevalent and fatal. Forests act as regulators to diminish excessive and to increase insufficient moisture. The beneficial influence of pine forests on pulmonary diseases is universally recognized.

In a word, then, the forests are an absolute necessity. If we would have the advantages referred to, with many others not discussed, we must have the forests near us. Mild winds, humid atmosphere, equable climate, regular rivers, a flourishing agriculture, an expanding industry, are things we can not import, and they are all things which depend for the very possibility of their existence on the presence of forests, and extensive forests, within the bounds of our own country and distributed where they will do most good.

The experience of the race and the investigations of science agree in testifying that there is a certain ratio which the forest land of any given country (varying of course with the country and even with different parts of it) should bear to its other lands, and that if the forested region is allowed to sink below that ratio, either through carelessness or a selfish desire to get all the advantage out of the resources of a country for the present generation, regardless of the interests of posterity, the result can be only an impaired industry and declining prosperity.

Even if all the land of a country were good agricultural land, the plan of clearing it entirely off in order to put it under cultivation would be strikingly like the old folly of killing the goose that laid the golden egg; for not only would no increased yield of agriculture occur as the result of such a policy, but a greatly-decreased return would probably be the result, diminished to the lowest point and ending in the utter destruction of agriculture and all other industry in one common ruin.

The importance of forests then for the national welfare being admitted, the question remains to be considered, What is the condition of our forests, and what action should be taken in their behalf? It must suffice in regard to this to refer to the facts contained in the various census reports, the bulletins of the Department of Agriculture, and the numerous other publications in which the past condition, present state and future prospects of our forests are discussed. The evidence is ample and conclusive that we are making fearful inroads on our forest stores. We are cutting off a much larger crop than can possibly be replaced by natural growth within the period when, at the present rate, we shall have cleared the original forest off the ground. We are doing almost nothing in the direction of cultivating forests; nay, we are not even protecting from devastation the young trees which might replace the forests if they had a fair chance for growth.

It is not the farmer—who only clears the forest in order to sow his crops, nor the lumberman—who fells the trees for the purpose of sending the lumber to market, nor the railroad—which calls for our forest trees for its ties, nor even the settler—who wants fuel to keep him warm, who are the enemies of our forests. All these at least obtain from this moderate destruction some return for themselves and society which is great and visible, though not always commensurate with the damage they inflict by their careless and wasteful methods. Fire, however, and browsing animals of all sorts inflict a damage on the growing forests for which there is either no return at all or one so insignificant as not to be worth mentioning. These two agencies, between them, keep millions of acres free from trees which would soon be covered with dense forests if they could be protected from such spoilers for a few years.

It is estimated on good authority that within fifty years, at the present rate of cutting, and with the present wasteful methods of management, the great bulk of our valuable forests will be gone, with almost no prospect of seeing them replaced by a new growth possessing anything like the value of the present one. To put it mildly, we are using up our forests at a much more rapid rate than we are replacing them. We are already beginning to experience some of the most serious evils of such a policy in a growing scarcity of valuable timber and in the changing character of our streams, soil and local climate. And these evils are bound to increase with every year of continuance in this line of action. Such being the case, the question as to efficient remedies becomes all-important.

Before mentioning the various measures of relief to which I believe that it would be wise to have recourse, and which I think will in their main outlines have to be adopted before long, if we are to avoid the losses which will inevitably accompany our present policy, I wish to call attention to some important distinctions in terms. I would emphasize the fact that *tree-planting* is not *forest-culture*. The two are quite distinct in their methods, in the persons who manage them, and to a large extent in the purposes which they subserve. The term tree-planting I shall apply to the system of planting trees which a farmer may carry on in connection with his agricultural operations from a variety of motives, such as beautifying his farm and house yard, shading his cattle in the fields, protecting them or his fields from the blasts of winter by cultivating wind-breaks, planting them along the water-courses to keep the soil from being carried away by sudden freshets, etc. Forest-culture I shall apply to the regular system of cultivating extensive tracts of country with a view to securing as large and valuable a stand of trees as possible. This also may be done from a variety of motives, as when done by government or corporations with a view of affecting the climate and preserving the rivers and soil of the mountains, etc. The difference consists chiefly in the fact that in the one case tree-planting is done as a mere incident with a view of enhancing the value of other forms of property with which it is intimately connected, while in the other case it is the chief business, and the ground is given up entirely to this one crop and is managed with reference to its prosperity. The former can be done, of course, by every farmer or owner of a lot which he devotes chiefly to other uses, while the latter can be done only by those who give up their whole land to this one purpose. Tree-planting, however extensive it may become, can never take the place of forest cultivation. The former would, of course, be done only by people in places where they live and cultivate the fields, while the forests must be kept up often on sterile and, for agricultural purposes, good-for-nothing soil, where no farmer could make a living. To secure, moreover, the meteorological advantages of forests and the indirect industrial benefits which flow from their regular maintenance, it is absolutely necessary in certain conditions that they should cover a large extent of contiguous ground, stretching often for miles. It is evident that such work can not be done by a small farmer in the time and with the means usually at his command.

Another point must be insisted upon, and that is that forest preservation does not at all mean that trees shall not be cut down, but simply that they shall be cultivated just like any other crop, and not wasted; that they shall not be taken away before they are ripe for use, except for some special reasons, and that the conditions necessary for reproduction shall be steadily maintained from year to year. This means, oftentimes, that care must be exercised not to allow the stand of trees to be cut off entirely or all at once, since this sometimes so changes the whole character of the soil and climate as to make it impossible to recover the ground with any reasonable expenditure of effort. It is from this wholesale and inconsiderate cutting that such immense damage is being done in all mountainous regions by the clearing of the forests from the hill-sides. The soil is left exposed to the free action of the frost and rain and is carried off in such quantities as to leave only the bare rocks, on which nothing can take root. Even if the soil should not be carried off, the beating rain and driving storm, the scorching sun and biting frosts will dry up, freeze out, drown out, or sweep away whatever seedlings might spring up there. The judicious cutting of a forest in a climate like that of the Atlantic or Pacific coast regions, says Dr. Sargent, entails no serious or permanent loss. A crop ready for the harvest is gathered for the benefit of the community. Trees which have reached their prime are cut instead of being allowed to perish naturally, and others take their place. In this way the permanence of forests is secured while their fruitfulness is kept at the maximum, if we consider, say, a century as the unit of time.

Now, I believe that our own brief experience confirms that of the various European countries and is in full harmony with the *a priori* deduction drawn from a study of the problem, viz, that a wide and intensive care on the part of the Government is indispensable to insure the preservation of the necessary forests. As already shown, our Government has never taken it for granted that any branch of industry would flourish to the desirable extent if left to itself. Much less likely is forestry to flourish, if left to itself, than other branches. A very short glance at the history of our forests is sufficient to show why they have been disappearing so rapidly.

The farmer has cleared off, perhaps, as many acres as the lumberman, it may be more; but he has cleared the ground for the purpose of cultivating it, and though it is undoubtedly true that in some localities he has pursued a short-sighted policy and cut off an excessive amount of the forest, yet on the whole most of the clearing he has done has been of a character that has contributed to increase the total wealth, present and prospective, of the community. This can not be said to the same extent of the lumberman, who has often cleared the forests from ground which was really good for nothing but to grow forests. Until a very recent period it was possible to get possession of forest lands for a mere song. A company having once put up its mills, found it for its interest to use up the supply of material as soon as possible and then to change the location of its works. Such enterprises had little interest in the welfare of the region within which the mills were situated, for they did not expect to stay longer than was necessary to make use of the wood which was suitable for their purposes. They cared still less for the interests of the dwellers in the valleys of the water-courses which their policy was converting into entirely different sorts of streams. They hoped to make more money by cutting down the trees as rapidly as possible and then moving on than in any other way, and as it was money alone which they were after they did what promised to give them the biggest and quickest returns. From their stand-point it was all right, and just what everybody else in society would have done if he had had the chance, but it was none the less ruinous to the interests of those who were affected by it. The feeling of the injured had little chance, however, to concentrate itself against any one, as the aggressors were often far removed from the scene of operations which affected them, and the injured were, moreover, ignorant of the true cause of their losses. In a word, it is to the pecuniary interest of the lumberman to cut as fast as he can, since the more he cuts the more money he makes, and if the supply gives out he can move on to where there is plenty of it. What does he care even if the supply will come to an end in twenty or twenty five or fifty years? That is a long way off, and after him the deluge. Now, I think that no one can doubt that it was a short-sighted policy for our States and the nation to be so free with their timber resources as to hand them over without control of any sort into the hands of private parties to do with them as they chose. The nation never thought of doing anything of the sort with its streams. They were looked upon from the very first as things in which all had an interest and which the Government should protect in the interest of the whole. But with that curious inconsistency which characterizes all men more or less in their political and social relations, but especially the Anglo-Saxon, while we prescribed punishments for all who polluted or filled up or diverted our streams, no matter how convenient it was for them to do so, no matter how much they may have saved or made by so doing—we have had nothing to say to him who was slowly drying up the very sources of the streams by cutting away by wholesale the trees that protected them.

It must seem to a disinterested student of human affairs a strange thing that a Government will protect the farmer by its police force against the thief who would take a bushel of corn, but will do nothing with him who steals away the fertility of his field by drying up his water supply; or, indeed, will prevent a brother farmer from turning aside a portion of the stream which has always flowed through his farm, but will say nothing to him who causes the whole stream to dry up and disappear at one time, and reappear at another as a raging torrent threatening to sweep away his most valuable acres; or will protect him against the assault of a bodily aggressor, but do nothing with the man who steals away his health by altering the whole character of his air and climate.

Strange it would seem to be that a Government will establish an agricultural school where the scientific side of agriculture can be studied, experiments made on crops and soil, etc., and spread abroad at public expense the results of such experiments, and yet make it no part of the duty of such a school, nor offer any inducement to any one to undertake the investigation of forestry, which underlies and conditions the very possibilities of a flourishing agriculture. Strange that it will spend large sums of money in growing and distributing freely to farmers seeds of various kinds of plants, while it has as yet done little or nothing toward the same kind of thing in regard to trees, the growing of which under some sets of conditions would be as profitable as that of any of the new kinds of crops which it would introduce. Strange that it will establish agricultural fairs and offer premiums for excellence in all branches of agricultural work and yet not notice a work which is of vital and fundamental importance to the whole industry of the country.

All this however is spilt milk. What has been done has been done and can not be helped. Its consequences may perhaps be obviated somewhat. What has been left undone has been left undone, and we can not remedy the evil except by inaugurating a different policy.

The first step is for the Federal and State governments to remove the timber lands which still belong to them from the list of lands for entry or sale, and, after a thorough examination as to what forests are of climatic and industrial importance, to keep them under the control of the Government. There are in the older States perhaps few such lands of any considerable extent, but such as there are should be retained in public possession and managed in the interest of the whole.

As to the lands which have passed into private possession it is more difficult to do anything, and I think that better results can be achieved by adopting a line of action, which I shall outline presently, than in trying to restrict or control lands which have finally passed over into private possession.

To insure the most complete success in this work of protecting and promoting the growth of forests it will be necessary to have hearty co-operation between the State and national governments. A word, therefore, may not be out of place in this connection as to what the State governments may properly do in this direction, though they can accomplish but little unless the Federal Government does its part.

One of the first and most important measures which the individual States may wisely adopt is to take some steps which will attract public attention to the vast importance of the matter, and which will interest the great mass of the people in some active work of their own in connection with the subject. This can be done, I think, by some general plan of encouraging tree planting on the part of our farmers. To do this in any satisfactory way it is necessary to devise some method of reaching the great mass of people and fixing their attention, if it be only for a short time. This, I think, can be secured by the establishment in the proper manner of a State holiday, to be called Arbor Day, and insisting, so far as possible, on its general observance by all the people in the State. But this of itself would not be enough. Men must be provided whose business it should be to make a thorough study of the subject of forestry in general and the business of tree planting in particular; as to the kind of trees it would pay best to plant in each locality, the methods of culture, the influence of trees on the farm, etc., and who should go to agricultural fairs and farmers' meetings, and impart the instruction which the average farmer is wofully in need of. They should also go into the teachers' institutes, especially in the rural districts, and try to interest the teachers in a matter which they would have rare opportunities to urge upon their pupils, who will shortly be the controlling element in the State. Means of publication should, of course, be amply provided, so that they could reach with their publications and lectures every farmer in the State. These lecturers should make it a special point to show how a wood-lot or even isolated trees may be utilized so as to return the largest yield to the farmer.

The State would find it for its interest, also, to establish nurseries where seeds of trees or young trees could be obtained at a nominal price, or for nothing, as experience might demonstrate to be the best plan. Premiums also should be offered for the best groves or groups, or samples of trees of various kinds, for the best utilization of tree products, etc. For, in the long run, this element would determine how large a per cent. of the farmers would really go into the matter.

It may be objected to this plan that it is not necessary, since farmers are alive to their own interests, to lead them to take up any such thing of themselves. This, I think, is entirely a mistaken notion. In the first place, under present conditions it is very questionable whether it would pay farmers to take up tree planting on a large scale as a mere matter of dollars and cents. They know very little of the subject. It would cost entirely too much to get the education necessary to make such a thing profitable for any farmer to undertake it on his own account. On the other hand, if the necessary information was brought home to him by a skilled expert in such a form as to be thoroughly intelligible to him, it might pay him well to engage in it. Moreover, it is a well-known fact that if a custom once creeps into a farming community and naturalizes itself, so to speak, among a few of the best farmers, it oftentimes takes root and grows, when if it had not come so recommended and pushed by strong public influence it might never have come at all. The introduction of nearly all public improvements amply proves this. It is as well established, for instance, as anything can be in agriculture, that at a certain period in the development of the industry of the country the introduction of improved breeds of live stock will result in enormous profit. But the larger part of the agricultural regions of this country, although they have long reached that period, still worry along with the old style of spindle-shanked draught horse, the long-nosed swine, and the scrub cow. Nearly every good thing is the result of the determined effort of public-spirited citizens, or of the Government, or the pushing commercial spirit of the manufacturer or merchant who has made or bought something which he wants to sell. Of these means the Government offers, so far as forestry is concerned, in the long run, the only sure and permanent one, as in nearly every other sphere of education.

But this knowledge itself which is to be distributed must first be acquired; for it is safe to say that it is not now in existence. To acquire it will cost considerable money and many years of effort if the private individual is to do it alone and at his own expense. It can be obtained only as the result of careful experimentation on the growth and cultivation of all the different kinds of trees which will grow in this climate, and which are of any considerable value. This can be best done in connection with a regular school of forestry, where all the problems relating to kinds and values of trees, growth and cultivation, management of stretches of woodland, the effect of forests on climate and health, their economic aspects, and the other countless elements of this great subject of forestry are thoroughly studied. Such a school of forestry might and should be established in connection with the several agricultural colleges and experiment stations which have been so liberally endowed in all the States by the Federal Government, and which will be undeserving of their name if they fail to give instruction on a subject so vitally connected with agriculture and the general interests of the country as is forestry.

At such a school as this could be trained the men who could manage extensive tracts of forest lands in the ownership either of private individuals or of the State. But all these measures, important and valuable as they are, would not be sufficient by any means to insure satisfactory results at the present juncture. In order to make them of any permanent value they must be accompanied by a radical and far-reaching policy of governmental encouragement and management.

The States and the nation should encourage the planting and cultivation of large forests. Mere tree planting will never meet the requirements of the case. Large tracts of contiguous forest land must be maintained, if we are to get the industrial and climatic advantages which flow from a well-wooded country. The time has come when it may be profitable for private citizens as a mere means of acquiring wealth to plant and cultivate forests; profitable, I mean, if they have the knowledge in regard to local conditions which it should be the duty of the State to furnish through such forestry schools. To manage such forests so as to make them profitable requires a high degree of administrative talent and trained technical skill such as is rarely acquired by any great number of men except in connection with a regularly equipped school. If the trained men are at hand, and can be obtained, and the evidence is forthcoming that the cultivation of forests is likely to prove profitable, we may expect to find many corporations or individual men going into the business from purely pecuniary considerations, and thus we should enlist private interest in the cause of public welfare, as we do in other branches of industry.

But though I believe, judging from the experience of foreign countries and from the probabilities of the case, that we should thus get many men interested in extending and maintaining our forests, I do not think that this will be sufficient. We shall never have a thoroughly or even an approximately adequate remedy for the evils which beset us in this matter until the States and the nation undertake the planting and cultivation of forests on a large scale.

In the first place it is evident that in the case of the large percentage of forests which, on account of meteorological considerations, must be maintained under unfavorable conditions, such as those remote from large streams and railroads, which would facilitate transportation, there can be no sufficient inducement for private capital to seek such an investment. If the enterprise will not pay good returns we can not expect private parties to take it up, and much of the reforesting or new afforesting which is most necessary for climatic reasons is of this character. It is, moreover, unsafe to have forests of this kind in private hands, since there is no foretelling at what moment private interest might lead to the cutting off of the forest from localities where they could be replaced only with difficulty, if at all.

Moreover forestry, at the best, is an industry of such peculiar character that it is very doubtful indeed whether, even under the most favorable conditions, it can ever attract the investment of private capital to such an extent as to furnish forests of the necessary size and quality. It requires, in the first place, a large capital, which of course cuts off most individuals from any hope of engaging in it. It requires, moreover, the use of capital for a long time with no return at all, and as most people prefer to risk their money where there is hope of large and quick profits rather than where there is certainty of no return for years to come (no matter how sure it may be in the long run), this still further limits the number of those who are willing to go into the business. It requires, moreover, a regular supply of highly trained labor for the efficient working of the forests, which it is difficult to get unless there are such schools as before mentioned and a reasonably certain career for those who prepare themselves for such work.

Another peculiarity of the business, viz, the great value of the stock on hand after the forest is fairly started, is a constant temptation to spendthrift owners to clear the ground at once, in order to realize immediately, and where land changes hands so rapidly as in this country there is of course great probability that it will sooner or later fall into the hands of such a man, who can do more damage in five years than a successor can make good in fifty.

All these considerations justify, on theoretical grounds, the conclusion to which our own experience points and which that of Europe absolutely demonstrates, viz, that we can not rely on private enterprise to conserve the interests of the public in this regard. On the other hand, there are comparatively few objections to Government ownership and management of forests on the ground of efficiency. The characteristics of the business coincide very closely with those which modern economists have enumerated as necessary to any business which Government should undertake. European experience, moreover, has fully demonstrated that Government management may be quite as efficient as the best private management. Indeed the state forests have become the models which private owners imitate, and they count themselves happy if they can equal them.* European Governments, after having to a very large extent followed the advice of the orthodox English economists and gotten rid of the forest lands which from time immemorial have belonged to the state, are now trying to get back large tracts of them into the possession of the state. The attempt to control private owners in the use of their forests has broken down in Europe nearly as completely as it would do here. There is a reason in our society why the state should undertake this branch of business which does not exist to the same extent in Europe. We have no old families with vast landed estates handed down unimpaired from father to son which offer a good basis for forest management. The only person, natural or artificial, in our society fit to do this is the state. I would not be understood as arguing for state monopoly of forests. On the contrary, I think the state should encourage private individuals to engage in forest culture on a large scale, but I think that it will never succeed in getting them to do so to such an extent as to do away with the necessity of planting and maintaining forests on its own account, which it will need to do, partly because many of the forests most required will offer slight inducements or no inducements at all to private capitalists, and partly for the sake of conducting model forests in connection with its schools of forestry. The best if not the only way to secure the development of private forests, even to the extent which is possible under the best conditions, is to have the state take the initiative in planting and caring for forests. The function of state forestry is not merely to secure the existence of certain public forests, but also, and perhaps quite as much, to encourage private forests by showing the proper methods of cultivation and utilization of forest products. Men do not like to put their money into an entirely new branch of business. They like to know that somebody has entered the field, if only as a pioneer, and has achieved satisfactory results.

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* From recent reports in regard to the German forests it appears that in 1884 Baden, with a forest area of only 234,000 acres, had a net income of $578,000. Wurtemburg, with 476,000 acres, had a net income of $1,237,600. Saxony from her 403,000 acres of timber lands derived a net revenue of $1,588,325, while Prussia, with a large part of her forest area unproductive and undeveloped, shows a gross income from the State timber lands of more than $2 per acre. The net income from year to year of all the German forests—equal in area to the forests of New England, New York, and Pennsylvania—is estimated at $57,000,000. This it must be understood is derived under the most conservative management, which harvests only what yearly grows and spends considerable sums for improvement of the crop and recuperation of waste areas.

It may be said that we have already experience enough to show that forestry may become a profitable branch of business of private parties. The trouble is that our experience on that subject is exceedingly small, that it moves very few to enter the business, and our forests disappear much more rapidly than such favorable experience accumulates.

It is superfluous to say that the State and the United States Governments should establish and enforce laws which would put an end to the criminal destruction of our forests by fire and browsing animals.

The whole subject, then, may be summed up as follows:

We are wasting our forests—by the ax, by fire, by pasturage, by neglect. They are rapidly falling below the amount required by industrial needs, by our water supply, by our rivers, by our climate, by our navigation and agriculture. It is high time to call a halt. The devastation of the ax will probably go on in the forests owned by private parties. Other forms of devastation can and should be stopped by rigorous measures on the part of the Government.

Our only hope is to save what forests we have still in the public possession, so far as they are necessary to the prosperity of the country, by not allowing them to be cut except under such conditions as will keep the forests in good condition; to encourage tree-planting and forest-planting on the part of individuals, corporations, and communities; and above all, as forming the condition on which the rest will be of any avail, to insist that the States shall undertake the systematic cultivation of forests in those places where it may be necessary to preserve our streams and climate.

Some one may ask where the Government is to get the authority for this purpose. In the case of the Federal Government, the answer is easy. It still owns millions of acres of forest lands, which should instantly be withdrawn from entry and subjected to a searching examination, by experts, as to its character, reserving permanently to the Government those portions which are of fundamental importance to the climate, soil, and streams. In the case of the States much of the very land needed falls into their possession for non-payment of taxes. Let the States keep it. Much of the land needed can be obtained at private sale for a mere song. Let the States buy it. More, if necessary, can be obtained by the exercise of the right of eminent domain—let the States take it. Shall we allow a railway to take land, no matter how insignificant the line it proposes to construct or how few people it will benefit, and refuse to the States the right to take land for such a purpose as this, on which hangs the welfare of our whole people?

In all this we ask nothing more than that the State shall do for forestry what it has already done for mining, agriculture, trade, and transportation, and we ask it not so much in the interest of forestry itself as a separate branch of industry as in the interest of other industries whose prosperity depends on the continued existence of forests.

It will be noticed that in the preceding discussion we have not attempted to distinguish particularly between what the National Government and the various State governments should do, but have indicated rather what they should all do, taken as a whole. The particular part which each should do follows almost as a matter of course from a study of the relations of the different parts of our governmental system. Some of the things we have mentioned, most of them, perhaps, should be done by the States individually. But the Federal Government should certainly go on with the work it has begun in connection with the Department of Agriculture at Washington.

It should continue the work of acquiring and disseminating information, and for this purpose should establish experimental forests in different parts of the country, which should be well equipped and placed under the most skillful direction. It should certainly place a check on the exploitation of forests on Government lands, and withdraw what remains of our national timber lands from the clutch of the devastators and insist on some regard being paid to general interests by those who wish to utilize them. If there be no way to get the States to look after the matter themselves the Federal Government should take some steps toward reforesting the headwaters of our great navigable streams where they have been cleared off, and nothing is being done to protect them. Surely it is as legitimate to expend Federal money to keep the soil from flowing down our mountain sides and filling up our rivers as it is to expend money in clearing out their channels when once filled. It is surely permissible to expend Federal money to protect the stream itself if it be proper to stock and restock it with fish.

Our State governments should do the rest, and should begin soon. The expense of such a system, properly organized and carried out, will be defrayed ten thousand times by the great increase in national wealth and national health which will ensue, while the loss incident to a persistence in our present policy will be simply incalculable.

REPORT

ON THE

FOREST CONDITIONS OF THE ROCKY MOUNTAINS,

ESPECIALLY IN THE

STATE OF COLORADO, THE TERRITORIES OF IDAHO, MONTANA, WYOMING, AND NEW MEXICO,

BY

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Arapahoe County—Archuleta County—Bent County—Boulder County — Chaffee County — Clear Creek County — Conejos County—Costilla County—Custer County—Delta County—Dolores County—Douglas County—Eagle County—Elbert County—El Paso County—Fremont County—Garfield County—Gilpin County—Grand County—Gunnison County—Hinsdale County—Huerfano County—Jefferson County—Lake County—La Plata County—Larimer County—Las Animas County—Logan County—Mesa County—Montrose County—Ouray County—Park County—Pitkin County—Pueblo County—Rio Grande County—Routt County—Saguache County—San Juan County—San Miguel County—Summit County—Washington County—Weld County.

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MAP.—Showing forest areas and principal irrigating canals of the Rocky Mountain region.

LETTER OF TRANSMITTAL.

COLORADO SPRINGS, COLO., May 14, 1887.

SIR: Under dates of April 1 and September 27, 1886, respectively, commissions were issued to me from your Department, authorizing an investigation of the forest conditions and resources of the State of Colorado and the Territories of New Mexico, Wyoming, Montana, and Idaho, and an examination of the relations existing between the forests, water-courses, and irrigating systems of the region, with special consideration of the Government timber lands.

I have the honor to submit the accompanying report.

Upon receiving authority to conduct the investigation, correspondence was instituted with civil engineers and other well-informed persons in the several counties of the region, and printed circulars were sent out embracing the following questions:

CIRCULAR A.

(1) What is the extent of forest land in your county, giving approximate number of square miles; and in what part of the county is it mainly situated?

(2) What proportion of it is fully stocked; good for timber? What part of it brush, of promising growth? What part of it made waste by burning over?

(3) What is the proportion of forest to other lands?

(4) What is the character of the forest growth now remaining, in the size and kinds of trees?

(5) What species of trees predominate?

(6) Name, in the order of their importance, the principal uses to which each kind of timber is applied.

(7) What special dangers threaten the forests in your county, as lumbering, consumption by railroads, fires, etc.

(8) What are the chances for renewal after the forests have been destroyed?

(9) Of what species of trees is the second-growth usually?

(10) What kinds, if any, follow after the timber has been destroyed by fire?

(11) Is any planting done? And to what extent, and with or without irrigation?

(12) Have you noticed any changes in the volume of water in the streams, as the trees in their vicinity have been cut off or burned? Is there less water in the streams than formerly? Have floods and droughts become more frequent? Is the flow of water in the streams more intermittent?

(13) Are any observations on rain-fall kept in your locality? If so, by whom (giving name and post-office address)?

(14) Have any avalanches occurred in your section? If so, please give the particulars; when, where, and what, if any, loss of life and property?

(15) What measures would you suggest for more adequate protection of forest growth?

(16) Give any other information, upon the same general subject, which may occur to you. So far as possible, give definite and particular answers to the foregoing questions, and known facts rather than general statements. If there is insufficient space on this sheet for your answers, supplementary sheets may be used, care being taken to refer to the numbers on this sheet, so as to prevent uncertainty or confusion.

CIRCULAR B.

(1) Please give a brief and general topographical description of your county.

(2) What is the approximate total number of acres of land in your county, suitable for agricultural purposes, requiring irrigation?

(3) Is there a sufficient water supply to irrigate that amount? If not, what proportionate amount short?

(4) What is the approximate number of acres already under ditch?

(5) What is the approximate number of acres already irrigated?

(6) In your county, what is the approximate total length of: (*a*) Irrigating ditches? Main; secondary; small. (*b*) Mining and milling ditches? (*c*) City water-works (and capacity in gallons)? together with total capacity of each, in statutory inches or cubic feet, per second.

(7) Has the volume of water in the streams of your county increased or diminished, to your knowledge? Is the flow of water in such streams any more or less intermittent than was formerly the case? If you have noticed any such changes, please state the causes, so far as known to you.

(8) What effect, if any, in your opinion, do the forests have on the water supply?

(9) What, in a general way, is the extent, character, and location of timber in your county?

(10) Please note on sketch (to the best of your knowledge) the situation of the timber, irrigating and other canals, and city water-works in your county; giving the timber in black and canals and water-works in red.

(11) What are the principal causes of the destruction of forests in your county, and what measures would you suggest for their more adequate protection?

(12) Please give any other suggestions upon the same general subject which may occur to you. If there is insufficient space on this sheet for your answers, supplementary sheets may be used, care being taken to refer to the numbers on this sheet, so as to prevent uncertainty or confusion.

It also became necessary to conduct an extensive written correspondence, which extended through a period of about one year. Considerable interest was manifested in the general subject, and much valuable information was obtained concerning local forest conditions. The facts collected with respect to the numerous irrigation systems of the region were not so full and explicit as was desirable, but served a useful purpose in the preparation of my report.

Between the months of April and December, 1886, I visited many of the principal points in Colorado and the several Territories included in this examination. By personal investigation and inquiry in the various localities, I was enabled to obtain much useful information relating to the subject, and to verify statements derived from other sources.

For most timely and valuable assistance rendered me in this connection grateful acknowledgment is due to ex-Governor Benjamin H. Eaton, George G. Merrick, esq., Hon. William N. Byers, Capt. Edward L. Berthoud, C. E., Prof. A. E. Beardsley and Blair Burwell, C. E., of Colorado; Samuel Ellison, esq., General H. M. Atkinson, H. Hartman, C.

E., and Prof. Ad. F. Bandelier, of New Mexico; Governor E. A. Stevenson and Hon. Milton Kelly, of Idaho; W. L. DeLacy, C. E., Hon. Granville Stuart and Prof. O. C. Mortson, of Montana; Franklin O. Sawin, C. E., Hon. M. N. Grant and Frank Bond, esq., of Wyoming. Many others, who most generously and efficiently aided me in this behalf, can not here be mentioned by name.

In conclusion, permit me to say that this work has been one in which I have taken great pleasure, and though not unmindful of its imperfections and deficiencies, I trust it will in fair measure meet your expectations and be of service to the general public.

I remain, very respectfully, your obedient servant,

EDGAR T. ENSIGN,
Special Agent of Department of Agriculture.

Hon. NORMAN J. COLMAN,
Commissioner of Agriculture, Washington, D. C.

FOREST CONDITIONS OF THE ROCKY MOUNTAINS.

I.—GENERAL VIEW.

The forests of the Rocky Mountain region sustain an important relation to the western half of the United States, if indeed their influence is not more widely extended. In the past their value has been wholly measured by their yield of timber and other useful products, but a more enlightened estimate is now gaining ground. It is gratifying to note that a more just comprehension of their value and importance prevails, and that the indifference with which their partial destruction has been viewed is yielding to a desire for their preservation.

These forests are mainly situated upon the lands of the General Government, and are not subject to State or Territorial control. The measures in force for their maintenance and protection are extremely ineffectual.

GEOGRAPHY OF THE REGION.

In order to understand the existing forest conditions of this region it will be necessary first to consider its leading physical features.

The term "Rocky Mountains" (originally "Stony Mountains"), in its widest sense, includes all the mountains of North America between the Great Plains and the Pacific Ocean, extending to the Arctic Ocean on the north and to Mexico on the south. It is the opinion of many that the same system includes the mountains of Mexico and Central America. Exclusive of Mexico, the chain traverses the entire region embraced between the thirty-second and seventieth parallels of north latitude. Its greatest expanse is between the thirty-eighth and forty-second degrees of north latitude, where the system has a breadth of about 1,000 miles. Its highest peak is Mount Saint Elias, in Alaska, which rises to an altitude of 19,500 feet above the sea.

THE MOUNTAIN SYSTEM.

For the purpose of the present investigation, the term "Rocky Mountains" will usually be confined to those portions of the system which are comprised within the State of Colorado and the Territories of Idaho, Montana, Wyoming, Utah, and New Mexico.

The mountain system under consideration is situated midway between the Mississippi River and the Pacific Ocean, and running nearly parallel with these has a general course from northwest to southeast. It extends through seventeen degrees of latitude, reaching from the British Possessions to the Mexican boundary. Springing from elevated plains and plateaus, which range in altitude from 3,000 to 7,000 feet, the mountains of this system attain their greatest elevation in Colorado, reaching there an extreme height of 14,460 feet above the sea.

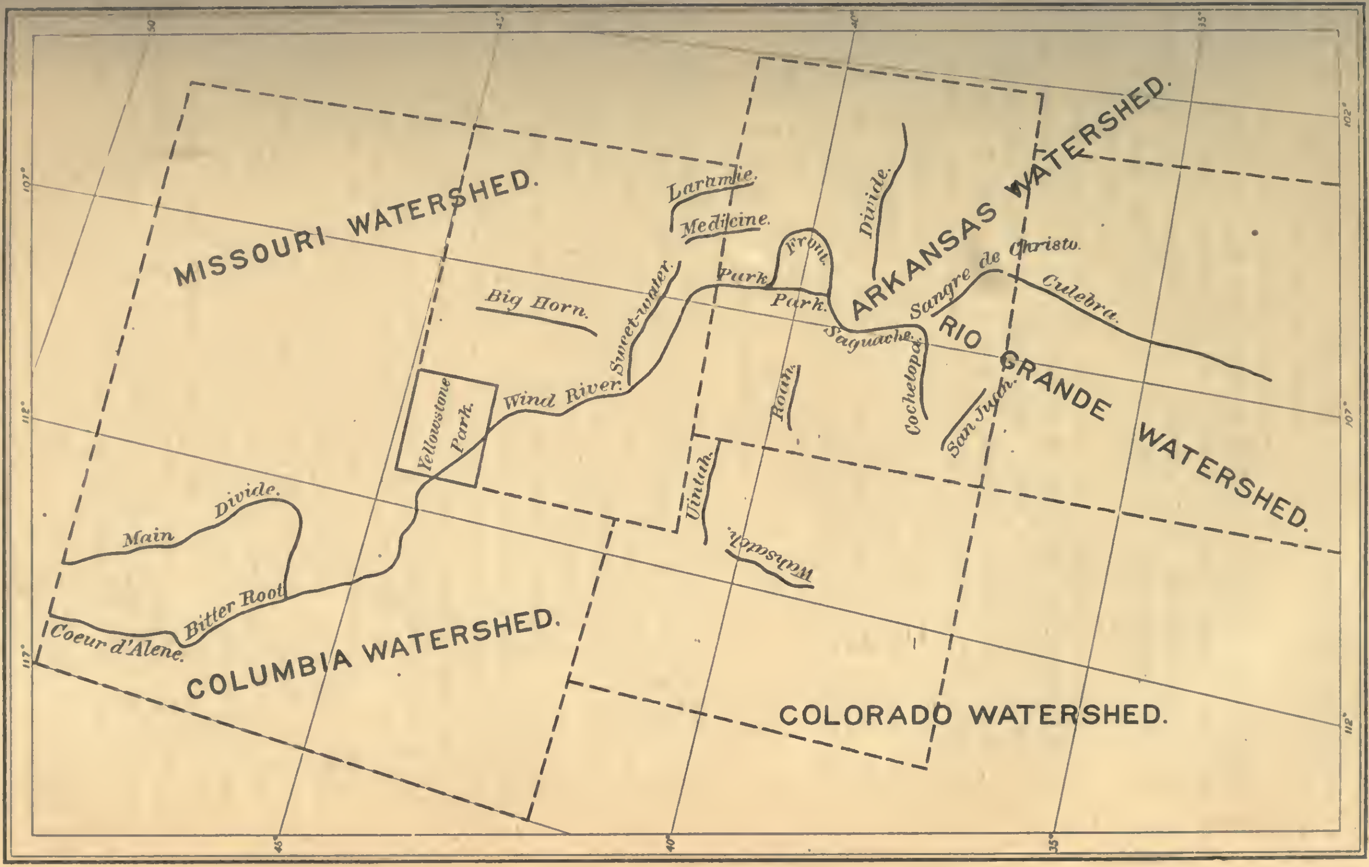
The several parts of the system may be described briefly as follows:

Commencing at the boundary line between British America and Montana, in the western part of the last-named Territory, the Main Range there takes a southeasterly course for a distance of about 200 miles; then it turns sharply to the west and at the boundary of Idaho is joined by the Bitter Root chain of mountains, which run in a southeasterly direction and form the middle portion of the dividing line between Montana and Idaho. The Coeur d'Alene Mountains, in northern Idaho, constitute the northwest extension of the Bitter Root Mountains.

The Main Range, from the point where it is joined by the last-named mountains, continues in a southeasterly course on the line between the two Territories and enters northwestern Wyoming near the southwestern corner of the Yellowstone National Park. Continuing in the same direction, the Wind River Mountains form an important link in the great chain. At their southeastern extremity they meet the Sweetwater Mountains, a comparatively short range, trending eastward. The crest, or dividing line, there turns to the southeast and passes over an open country or high table-land for a distance of 75 to 100 miles; it then strikes the Sierra Madre Mountains, the northern extension of the Park Range of Colorado, which form a portion of the Main Range. In North and Central Wyoming, the Big Horn, the Laramie and Medicine Bow Mountains are the most notable adjacent ranges.

The Colorado system commences on the north with the Park Range, which forms the western boundary of North Park. At the southwestern angle of the park the main divide turns directly eastward, separating North and Middle Parks, and is joined by the Medicine Bow Range at the northeast corner of the last-named park. The Main Range then bears to the southeast for a short distance, then turns southwestward and continues in that direction until it crosses the Park Range a few miles north of Leadville. The northern extremity of the Saguache Range is here reached. This range takes a course a little east of south, and terminates about 40 miles southeast of the town of Gunnison, in southwestern Colorado. A range called in part the "Cochetopa Hills," and running in a southwesterly direction, connects the Saguache with the San Juan Mountains. The latter, bearing southeastward, terminate near the southern line of the State.

The principal secondary range in Colorado is the Park Range, which constitutes the western boundaries of North, Middle, and South Parks, and is crossed, as before stated, by the Continental Divide. Other im-


MISSOURI WATERSHED.
ARKANSAS WATERSHED.
RIO GRANDE WATERSHED.
COLUMBIA WATERSHED.
COLORADO WATERSHED.
Laramie.
Medicine.
Divide.
Front.
Park.
Park.
Sangre de Christo.
Culebra.
Saguache.
Cochetopa.
San Juan.
Roan.
Uintah.
Wahsatch.
Big Horn.
Sweet-water.
Wind River.
Yellowstone Park.
Main Divide.
Bitter Root.
Coeur d'Alene.
50°
45°
40°
35°
107°
112°
117°
102°

portant ranges in Colorado, upon the eastern water-shed, are the Medicine Bow Range at the north, the Pike's Peak Range in the central section, and the Sangre de Christo, the Culebra, and Raton Mountains at the south. Upon the western slope the Elk and San Miguel, or La Plata Mountains, are the most prominent.

Thus far and until near the southern limit of Colorado, the Continental Divide has consisted almost wholly of high and rugged mountains. It here loses that character, and entering New Mexico bears southwestward through an open and broken country interspersed with detached mountain ranges.

Returning to the northern boundary of New Mexico, to a point some distance east of the central portion, it is found that the Culebra Range is prolonged southward for about 100 miles, or until it reaches the neighborhood of Santa Fé. There the bold continuous mountains give way to lesser ranges scattered at intervals throughout the Territory, but usually conforming to the normal trend of the general system. Including the mountains of Utah in the general system, the Uintah and Wahsatch Mountains are to be mentioned as important branches. The former are especially noticeable on account of their exceptional eastward and westward trend.

CONFIGURATION.

The Rocky Mountain region is of such great extent and its topography so extremely varied, that an adequate description of it would far exceed the limits of this report. Its leading characteristics only can be considered. The subject may be conveniently treated under the headings—Mountains, Plains, Plateaus, Water-courses.

Mountains.—The mountains of this region are generally massive and rugged. In their midst are vast solitudes, snow-clad peaks, precipices, rapid streams, and deep cañons.* At some points, however, the mountains rise so gradually from the plains at their base that the traveler easily ascends and passes over them, hardly realizing that he is crossing divides which separate great water systems. In still other localities, lovely mountain parks, wooded heights, and sheltered valleys beautify and soften the harsher features of the landscape. While the Main Range pursues, generally, a course from northwest to southeast, the system as a whole is much involved. The comparatively low mountains and minor ranges of western Montana, and the more rugged mountains separating Idaho from Montana and Wyoming, culminate in the magnificent peaks and ranges of the Yellowstone Park region. Here lofty mountains, cañons, water-falls, geysers, boiling springs, fantastic rocks, and other of nature's strange works combine to make this region the "wonderland" of America. In the near distance, at the southwest, the "Three Tetons," prominent snow-clad peaks, rise above the surrounding country.

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* Cañon or canyon (Spanish—a tube or hollow); a deep gorge, ravine, or gulch between high and steep banks worn by water-courses; a term in common use in the United States in the States and Territories bordering upon Mexico. (Fremont.)

In Wyoming the principal range follows a tortuous line from the northwest to the southeast. There is a break in its southern extremity, and other ranges flank it at various angles upon the right and left, separated from each other and from the Main Range by high plateaus, sandy plains, grazing lands, and fertile valleys.

In Colorado the system is complex in the extreme. The course of the Main Range is very irregular; other high ridges abut upon or cross it, and detached groups appear upon either hand. Natural parks of great magnitude, surrounded by high mountains and each containing the head waters of an important river, here constitute a marked and agreeable feature. The mountains, as well as the general level, are higher here than elsewhere, and the ranges more massive. From almost any of the snowy summits scores of others may be seen.

The Culebra Range of northern New Mexico is a continuation of the general system, and is similar in character to the Colorado Mountains. Many of the mountains in Montana have smooth slopes and rounded outlines. In other parts of the range they are generally rugged, many having serrated crests and angular peaks. The sides are often rocky and precipitous, and the summits, of naked rock, extend far above the limits of vegetable life.

The "ground plan" of this mountain system is so irregular and of such great extent that, in the absence of surveys, it is impossible to determine its area with any degree of certainty. A conservative and approximate estimate would give it a length of 1,500 miles and an average breadth of 200, or a total area of 300,000 square miles.

Although the general course of the system is in one direction, the ranges, spurs, and groups lie at many and varying angles, and present the utmost diversity of form and exposure.

At the base of the mountains, on the east, are foot-hills and high mesas,* and these merge into wide, rolling plains. On the west the mountains are bounded by foot-hills, mesas, elevated plateaus, and wastes of sand and lava. In many places appear water-courses, canyons, and valleys.

Plains.—Second only in importance to the mountains are the Great Plains, which bound the mountains on the east for almost their entire length and extend hundreds of miles to meet the prairies of the Central Basin.

The western border of this region, adjacent to the range, varies in altitude from 3,000 to 6,000 feet above the sea, the greatest elevations being in Wyoming, Colorado, and northern New Mexico; thence sloping to the north, east, and south, coincidently with the direction of the principal water-courses.

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* *Mesa* (Sp.), the common name for the table lands (which are usually quite arid) in central and western North America.

The surface of the Great Plains is usually gently rolling, but in some localities buttes,* headlands, and detached masses of rock vary its otherwise monotonous aspect. The soil is generally a light mold, from 10 to 15 inches in depth, resting on a bed of sand, gravel, and bowlders. In some places there is considerable clay mixed with the surface soil.

In their natural condition the plains, mesas, and foot-hills are generally covered with a short but succulent grass. Some portions produce sage brush, among which nutritious grasses are interspersed. In other parts sage brush is the only growth. A comparatively small proportion is wholly barren.

Plateaus.—The great plateaus upon the western flank of the mountain system have a mean elevation of about 7,000 feet above the level of the sea. They extend from southern Wyoming through western Colorado and eastern Utah into Arizona and New Mexico, and are there lost in low desert plains.

By faults in the geologic structure, and by lines of cliffs and deep canyons, the various plateaus are separated one from another. Their general level is broken by mountains—single and in groups—buttes and towering escarpments of rock. Some thirty mountain peaks, ranging in altitude from 10,000 to 12,000 feet above the sea, have here been noted. The few streams of the region find their way through canyons, the walls of which are of immense height. Aridity is the prevailing condition, and vegetation is dwarfed and scanty.

Water-courses.—That the main crest of the Rocky Mountains constitutes the "Continental Divide" or line separating the eastern and western water systems is known to all; that there is also a great Transverse Divide, forming northern and southern water systems, is not so generally understood. Commencing in the northwestern part of Nebraska, the divide last named runs westward through central Wyoming to the southern border of Yellowstone Park; thence southwestward to the northwestern corner of Nevada.

Hence there are four great basins; one sloping to the northeast, drained by the waters of the Upper Missouri; one at the northwest, drained by the Columbia River; one at the southwest, which is double and discharges its waters into the Great Salt Lake Basin and the Colorado River; and one at the southeast, which is drained by the Arkansas and Rio Grande Rivers and their affluents. These several systems radiate from a common center, and have their sources in the high and snowy mountains of Wyoming and Colorado. The fact, however, should not be overlooked, that other and surrounding parts of the Rocky Mountain region largely contribute to the volume of water in the principal streams.

In considering further the several systems here outlined, it appears that at the northeast the South Platte rises in South Park and the

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* Butte (Fr., pronounced *bute*), an isolated peak or elevation of land in the central and western parts of North America (too high to be called a hill or ridge, and not high enough to be called a mountain).—(Webster.)

North Platte in North Park, Colorado, the two rivers flowing eastward and uniting in Nebraska.

At the northwest the Big Horn, Yellowstone, and Upper Missouri Rivers rise within or near the Yellowstone Park, and find outlet through the channel of the Missouri. Crossing the Continental Divide westward, it is found that Clark's Fork of the Columbia, the Salmon River, and Lewis or Snake River, also rise in the same region, but, as tributaries of the Columbia, send their waters to the Pacific Ocean.

In the southwest the principal streams flowing into the lakes of the Great Salt Lake Basin are the Bear, Weber, and Sevier. The Green River, which has its source in the Wind River Mountains, Wyoming; the Grand River, which drains Middle Park, Colorado, and the San Juan River, which rises in the southern part of the same State, unite in southern Utah and form the Colorado River of the West.

The Rio Grande and Arkansas Rivers drain the southeastern portion of the Rocky Mountain region. They have a common origin in the mountains of Colorado, but the first seeks an outlet directly in the Gulf of Mexico, while the latter, at a point some 800 miles northeastward, unites with the Mississippi river.

The Rio Grande, Arkansas, North and South Platte, and their main affluents, debouch upon high planes which slope rapidly to the south and east; and while the most of these streams pass through deep canyons in emerging from the mountains, they flow with a rapid current (descending from 5 to 8 feet to the mile) in shallow channels. Therefore it is not difficult to utilize their waters for irrigation and other purposes.

In Montana the plains have much less elevation than in the region southward, and the principal streams, the Upper Missouri and the Yellowstone, following a long and devious course to the junction of the two, have a gradual descent and sluggish flow; hence it is not easy to bring their waters to the level of the adjacent country. What can be done there by a system of reservoirs which will save the flood waters of spring and early summer, is a question for the future.

In Idaho, upon the western slope of the range, the principal streams flow rapidly, through arable valleys, and the waters can be easily utilized.

Southward, in western Colorado, the streams, in descending from the mountains, have a swift current and pass through valleys of much natural fertility. As they approach the plateau region, farther south and west, some of them enter profound canyons, and thus are lost for irrigating purposes.

ALTITUDES.

The altitudes of the Rocky Mountain region, inclusive of the valleys, plains, and plateaus, vary from 680 feet above sea-level at Lewiston, Idaho, to an extreme height of 14,460 feet in the mountains of Colorado.

The average or mean elevation of the several political divisions is given by good authorities as follows: Montana, 3,000 feet; Idaho, 4,700 feet; Wyoming, 6,000 feet; Colorado, 7,000 feet; New Mexico, 5,600 feet.

The approximate mean elevation of the Idaho and Montana ranges is 8,000 feet; of the Wyoming ranges, 9,000 feet. The mean height of the Colorado and New Mexico system, south to the latitude of Santa Fé, is about 10,500 feet.

In Montana two mountains reach an elevation of 8,355 and 10,629 feet respectively. Eleven peaks in Idaho range in height from 9,100 to 13,691 feet. In Wyoming fifteen of the principal peaks range in altitude from 9,273 to 13,790 feet. The best known and named peaks of the Colorado system, sixty-seven in number, vary in height from 10,906 to 14,464 feet. Seventy-two other peaks in the same State, between 13,500 and 14,300 feet in height, are unnamed. Two prominent mountains in New Mexico have an elevation, one of 11,200 feet and the other of 12,202 feet; while Utah boasts of seventy-five peaks above 10,000 and fourteen above 12,000 feet, the highest being Mount Emmons, with 13,694 feet.

*Elevation of timber-line on some of the mountains in the Rocky Mountain region.**

[Taken from Dictionary of Altitudes, U. S. Geological Survey.]

Mountain.	Timber-line.	Mountain.	Timber-line.
COLORADO.	*Feet.*	COLORADO—continued.	*Feet.*
Arapahoe Peak	11, 100	Long's Peak	11, 100
Mount Audubon	11, 325	Massive Mountain	11, 607
Bald Mountain	11, 100	Park View Peak	11, 100
Buffalo Peak	12, 041	Pike's Peak	11, 720
Mount Byers	11, 490	Mount Powell	11, 600
Crestone	12, 107	Mount Princeton	11, 500
Cunningham Pass	11, 500	Red Mountain	11, 746
Mount Elbert	11, 871	Mount Rito Alto	11, 817
Mount Engelmann	11, 578	Sierra Blanca	10, 410
Mount Evans	11, 723	Mount Silverheels	11, 549
Mount Evans	11, 300	White Rock Mountain	11, 919
Gray's Peak	11, 100		
Grizzly Peak	11, 758	MONTANA.	
Mount Guyot	11, 811		
Hamilton Pass	10, 840	Mount Blackmore	9, 550
Mount Harvard	12, 117	Mount Delano	8, 784
James' Peak	11, 100	Electric Peak	9, 442
La Plata Mountain	12, 080		
Lillie's Mountain	11, 100	UTAH.	
Mount Lincoln	12, 051	Gilbert's Peak	11, 100

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*Capt. E. L. Berthond, a civil engineer, of Golden, Colo., and a good authority, referring to a mountain range about 8 miles southwest of Georgetown, Colo., says: "Across the narrow valley north of McClellan Mountain, and upon another high peak, the limit of tree growth exceeds 12,400 feet elevation on the south slope of that peak. Here can be seen *Pinus aristata*, some of the trees 2 feet in diameter and 30 feet high, that retain their hold and slowly increase in size, thus maintaining themselves in respectable numbers in spite of furious gales of snow and wind, and an extreme arctic cold."

SURROUNDINGS.

The "Great Plains" lie contiguous to and eastward of the Rocky Mountains, but how far to the east they extend—at what point the "plains" (so long a synonym for sterility) end, and the prairie, or fruitful country, begins, is not easily determined. It is safe to say, however, that the western portions of Dakota, Nebraska, Kansas, the Indian Territory, and Texas, partake of the semi-arid condition of the region of the plains and indeed constitute a part of it, and have identical interests. Their grazing and farming industries are conducted upon principles similar to those which govern the like operations of their neighbors westward, and dependence upon the streams flowing from the mountains is as marked in one instance as in the other.

Oregon and Washington lie at the northwest. They, also, in their eastern portions, require water for irrigation. Their great river, the Columbia, is kept at a navigable stage by the large tributary streams which flow from the mountains.

At the west and southwest, the contiguous Territories of Utah and Arizona fall within the Arid Belt. The needs of their increasing population and rapidly developing industries require that the timber and water supplies of the mountains shall be maintained in perpetuity.

CLIMATE.

The atmospheric conditions of the Rocky Mountain region, as affecting the life and health of those who are living under their influence, have been a subject of quite general interest, and thus the leading characteristics of the region in this respect are known to many.

A concise statement of the climatic conditions of the region is given in the official report for 1885 of Hon. Francis E. Warren, governor of Wyoming, to the Secretary of the Interior. I take the liberty of quoting as follows:

> Were it not for the heat of the tropical regions, which is distributed over the continent by atmospheric currents as well as by the thermal ocean and Gulf currents, the high elevations of the Rocky Mountain regions would be too rigorously cold for habitation. But through these tempering influences they are not only habitable, but delightful and healthful portions of the continent, far more so than the Atlantic coast, or the great river valleys which approximate the sea-level on either side of the great continental divide. The humid tropical winds and the equatorial warm Japanese currents of the North Pacific Ocean—which are similar to the Gulf Stream of the Southern Atlantic—reaching the western and southern shores of the continent, produce the mild and even temperature of these coasts and, with climatic modifications, extend to the elevated Rocky Mountain regions of the interior.
>
> These modifications are mainly produced by the high snow-capped and almost unbroken mountain ranges of the western coast—the Cascade and the Sierra Nevada, the latter of which is covered with dense forests to an elevation of some 8,000 feet, while still above this lies perpetual snow. These, to some degree, are barriers against the extension of the warm atmospheric currents of the ocean over the interior Rocky Mountain elevations. Hence, as these mild winds, heated by the tropical ocean currents, sweep over the snow-capped mountain ranges, and around their extremities, and thus pass over vast arid regions in their course to the great Rocky Mountain elevations, they become somewhat tempered, and give to them their salubrious climate. The moisture that comes upon the mountain ranges, in the way of rain, during the rainy seasons of the Pacific coast, is slight from January to May.

It may be said further, that the superior elevation of this great central plateau, its remoteness from the sea or other large bodies of water, the comparative absence of fogs and rain, and the prevalence of sunshine, have conduced to render the atmosphere of this region dry, rarefied, and wonderfully clear. Through its medium distant objects are seen with surprising distinctness. Its curative properties have made it a famous resort for health-seekers and tourists.

Again, it should be noted that the climatic conditions of different parts of the mountain region, though having common characteristics, vary in degree one from another. The great extent of the region, its varying altitudes, its irregular outlines and configuration, combine to produce in the various sections diverse atmospheric conditions. Hence the flora of the country is varied, and in connection with differing soils the productive capacities of its several parts vary in kind and degree.

A friend notes the difference between the climatic and forest conditions of the eastern and those of the western slopes of the Rocky Mountains, as follows:

> One of the principal effects of the main mountain range is to cause a much greater precipitation of moisture, in the form of snow or rain, upon the western than upon the eastern slope. Within such areas of greater precipitation the forest growth is denser and the trees larger and better developed than upon the eastern side. The streams are larger, the water-flow more evenly distributed throughout the year, vegetation more luxurious, and the natural pasture of native grasses is maintained until late in the year or until snow falls. Upon the eastern side there is greater necessity for a rigorous enforcement of the laws to save the few remaining forests.

The following communication, lately received from Mr. George Cornwall, of Gunnison, Colo., is of interest, as showing the comparatively humid conditions which prevail in some localities upon the western slope of the mountains:

> I send you a tabulated statement of the number of days on which we had rain or snow for the years 1882, 1883, 1884, 1885, and 1886 to June 1. This statement is taken from the diary kept on my ranch, in the valley of Ohio Creek, 7 miles north of Gunnison, elevation 8,000 feet above sea level. The rains and snows come mostly in showers—very few all-day or all-night storms. We are not in a stormy belt. Please remember that any report from any portion of Colorado, except the plains, is a local report, and another report of no more than 5 or 10 miles away might be very different.
>
> Castleton's or Baldwin's, 10 miles higher up our valley, would show, I think, double the amount of rain or snow we have here, and still higher in the mountains the amount of rain and snow would again be doubled.
>
> The climate of this western slope is moist. The prevailing winds are from the west, starting perhaps from the Pacific Ocean, and, passing over a vast extent of country, when they reach the western slope of the Rocky Mountains they precipitate their moisture. Evaporation at our elevation is of course rapid, but on our bottomlands we grow all vegetables and grains without irrigation. For grasses we irrigate thoroughly. Mesa land we have to irrigate.
>
> The preservation of timber as affecting the rain-fall is not an important question with us. We have almost too much moisture.

Table showing the number of rain and snow falls at a point near Gunnison, Colo., from August, 1882, to May, 1886, inclusive.

Month.	1882.		1883.		1884.		1885.		1886.	
	Rain.	Snow.	Rain.	Snow.	Rain.	Snow.	Rain.	Snow.	Rain.	Snow.
January				7		5		4		12
February				2		6		4		3
March				6		8		5		3
April				3		7	4	4		2
May			4	2	4	3	5		3	
June			6		14		3			
July			14		2		15			
August	8		10		11		12			
September	6		12		6		5			
October	1		3	2						
November		4		2				2		
December		5		11				4		

The following table, kindly prepared by Sergeant Hall, the officer in charge of the U. S. Signal Service station at the summit of Pike's Peak, shows the total precipitation and relative humidity at that point from the year 1875 to 1885, inclusive:

Date.	Total precipitation.	Relative humidity.	Date.	Total precipitation.	Relative humidity.
	Inches.			*Inches.*	
1875	24.74	78.4	1881	44.49	66.7
1876	23.87	67.1	1882	28.99	78.4
1877	25.58	68.7	1883	18.17	80.1
1878	42.99	61.2	1884	9.28	77.4
1879	39.82	49.4	1885	30.48	82.3
1880	40.65	55.3			

Yearly and seasonal averages at Denver, Colo.

[Compiled from thirteen years' observations.]

Season.	Temperature.	Maximum temperature.	Minimum temperature.	Relative humidity.	Rain-fall or melted snow.	Number of days on which rain or snow fell.	Number of clear days.	Number of fair days.	Number of cloudy days.	Number of sunny days.	Cloudiness (in tenths).	Wind direction.	Hourly wind velocity.
				Per ct.	*In.*								
Spring average	47.2	77.9	19.2	49.1	5.86	25	33	39	20	81	3.0	S.	7.3
Summer average	69.8	95.9	47.1	44.9	4.91	26	37	42	13	89	2.4	S.	6.1
Autumn average	49.6	80.6	19.8	45.5	2.34	15	49	29	13	86	2.2	S.	5.6
Winter average	29.8	62.2	—7.3	54.3	1.84	15	44	36	10	84	2.1	S.	6.2
Yearly average	49.1	79.2	19.7	48.4	14.95	81	163	146	56	340	2.6	S.	6.3

JOSEPH J. GILLIGAN,
Observer Signal Service, U. S. Army.

Yearly and seasonal averages at Santa Fé, N. Mex.

[Compiled from thirteen years' observation of the U. S. Signal Service.]

Season.	Temperature.	Relative humidity.	Rain-fall or melted snow.	Number of clear days.	Number of fair days.	Number of cloudy days.	Cloudiness (in tenths).	Wind direction.	Hourly wind velocity.
		Per ct.	*In.*						
Spring average	46.9	36.3	1.93	36.5	43.6	11.9	3.9	SW.	8.5
Summer average	66.4	42.8	7.56	28.3	50.3	13.4	4.5	E.	6.8
Autumn average	48.4	46.4	3 18	49.1	33.5	8.4	2.9	Var.	6.3
Winter average	30.2	53.3	1.90	41.8	34.4	14.0	3.5	N.	6.8
Yearly average	48.0	44.7	14.57	155.7	161.8	47.7	3.7		7.1

The following meteorological data are from observations taken at the U. S. Signal Service station, Santa Fé, N. Mex. The data for 1881 do not include the month of December for that year. During the years 1883 and 1884 the station was closed:

Year.	Mean Barometer.	Mean temperature.	Mean humidity.	Direction of wind.	Rain-fall.
1872	23.292	47.9	41.8	N.	9.89
1873	23.272	48.6	37.0	N.	9.73
1874	23.211	48.0	48.0	E.	19.83
1875	23.209	48.0	42.0	SW.	18.79
1876	23.256	47.6	52.9	E.	15.07
1877	23.266	47.6	43.3	E.	13.15
1878	23.251	47.5	42.1	N.	19.55
1879	23.299	50.2	39.8	E.	11.44
1880	23.269	45.4	44.6	SW.	9.89
1881	23.268	49.7	51.9	SW.	21.75
1882	23.238	48.3	41.8	E.	10.37
1885	23.297	47.7	53.4	N.	14.89

For the subjoined tables I am indebted to the courtesy of General A. W. Greely, Chief Signal Officer, U. S. Army.

Annual and mean annual temperature (in degrees Fahrenheit) at stations of the Signal Service, U. S. Army.

Stations.	1873.	1874.	1875.	1876.	1877.	1878.	1879.	1880.	1881.	1882.	1883.	1884.	Number of years.	Mean annual.
Northern Plateau:														
Boisé City, Idaho	.....	.....	....	...	.....	52.4	51.4	48.9	50.0	48.6	(1)	50.0	6	50.2
Lewiston, Idaho	.....	.....	....	.....	.....	.....	.....	49.5	51.1	51.6	50.3	49.4	5	50.4
Northern Slope:														
Assinniboine, Ft., Mont	.....	.....	.....	.....	.....	.....	.....	.....	.....	42.7	39.2	39.1	3	40.3
Benton, Fort, Mont	42.5	43.3	42.1	(1)	(2)	(2)	(2)	40.3	43.6	44.8	43.0	41.5	8	42.6
Custer, Fort, Mont	.....	.....	.....	.....	.....	.....	.....	43.0	45.3	45.2	(1)	40.9	4	43.6
Helena, Mont	.....	.....	.....	.....	.....	.....	.....	.....	43.8	43.8	42.7	40.2	4	42.6
Maginnis, Fort, Mont	....	.....	.....	.....	.....	.....	.....	.....	.....	....	39.5	38.1	2	38.8
Shaw, Fort, Mont	.....	.....	.....	.....	.....	.....	.....	.....	42.1	42.5	40.6	39.8	4	41.2
Deadwood, Dak	....	.....	.....	.....	.....	.....	.....	40.8	(1)	42.9	40.5	40.5	4	41.2
Cheyenne, Wyo	44.8	45.5	42.5	44.3	44.2	44.2	46.5	42.9	45.8	43.9	42.4	42.6	12	44.1
Middle Slope:														
Denver, Colo	48.1	49.8	48.6	49.5	48.8	49.5	50.8	47.4	50.8	50.3	48.8	49.5	12	49.3
Pike's Peak, Colo	.....	18.9	18.2	10.0	18.4	19.4	21.9	17.9	20.7	18.8	18.7	18.3	11	19.1
West Las Animas, Colo	....	.....	....	...	.....	.....	.....	.....	.....	.....	49.6	48.7	2	49.2
Southern Plateau:														
Santa Fé, N. Mex	48.6	[illegible].0	48.0	47.5	47.6	47.5	50.2	45.4	(1)	48.3	(1)	(1)	9	47.9

[1] Record incomplete.

[2] No record.

Annual and mean annual precipitation at stations of the Signal Service, U. S. Army, compiled from the commencement of observations to 1884, inclusive.

Stations.	Established.	1871.	1872.	1873.	1874.	1875.	1876.	1877.	1878.
Northern Plateau:		*Inches.*	*Inches.*	*Inches.*	*Inches.*	*Inches.*	*Inches.*	*Inches.*	*Inches.*
Boisé City, Idaho	July 1, 1877	....	....	....	....	....	....	....	10.21
Lewiston, Idaho	July 1, 1879	....	....	....	....	....	....	....	....
Northern Slope:									
Assinniboine Fort, Mont.	Oct. 6, 1879	....	....	....	....	....	....	....	....
Benton, Fort Mont.	Oct. 11, 1879	....	12.32	11.95	10.45	12.75	(1)	(1)	(1)
Custer, Fort Mont.	Dec. 5, 1878	....	....	....	....	....	....	....	....
Helena, Mont.	Oct. 15, 1879	....	....	....	....	....	....	....	....
Maginnis, Fort, Mont	July 14, 1882	....	....	....	....	....	....	....	....
Poplar River, Mont.	May 1, 1882	....	....	....	....	....	....	....	....
Shaw, Fort, Mont.	April 1, 1880	....	....	....	....	....	....	....	....
Cheyenne, Wyo.	Nov. 1, 1870	9.23	13.48	10.01	9.71	12.10	5.03	11.71	12.64
Middle Slope:									
Denver, Colo.	Nov. 19, 1871	....	18.05	11.81	13.46	17.25	20.12	10.38	15.51
Pike's Peak, Colo.	Nov. 1, 1873	....	....	....	26.86	24.74	23.87	25.58	42.87
West Las Animas, Colo.	Oct. 1, 1881	....	....	....	....	....	....	....	....

Stations.	Established.	1879.	1880.	1881.	1882.	1883.	1884.	Mean annual.	
								Years.	Inches.
Northern Plateau:		*Inches.*	*Inches.*	*Inches.*	*Inches.*	*Inches.*	*Inches.*		
Boisé City, Idaho.	July 1, 1877	17.63	10.66	13.56	14.43	(1)	21.05	6	14.59
Lewiston, Idaho.	July 1, 1879	....	17.41	20.56	14.74	15.83	21.71	5	18.05
Northern Slope:									
Assinniboine, Fort, Mont.	Oct. 6, 1879	....	....	....	12.76	15.10	25.67	3	17.84
Benton, Fort, Mont.	Oct. 11, 1879	(1)	(1)	16.81	10.18	13.01	(1)	7	12.50
Custer, Fort, Mont.	Dec. 5, 1878	....	19.65	11.88	12.05	13.84	16.60	5	14.80
Helena, Mont.	Oct 15, 1879	....	....	19.94	10.32	(1)	19.18	3	16.48
Maginnis, Fort, Mont	July 14, 1882	....	....	....	....	13.29	9.00	2	11.14
Poplar River, Mont.	May 1, 1882	....	....	....	....	6.22	10.25	2	8.24
Shaw, Fort, Mont.	April 1, 1880	....	....	14.77	14.21	12.64	13.64	4	13.82
Cheyenne, Wyo.	Nov. 1, 1870	7.34	8.38	11.88	8.61	19.24	15.54	14	11.07
Middle Slope:									
Denver, Colo.	Nov. 19, 1871	10.86	9.58	12.78	14.49	19.49	15.07	13	14.99
Pike's Peak, Colo.	Nov. 1, 1873	39.82	40.65	44.57	28.82	18.17	9.28	11	29.57
West Las Animas, Colo.	Oct. 1, 1881	....	....	....	....	11.12	15.70	2	13.41

[1] Record incomplete.

AGRICULTURAL CONDITIONS.

A well-known writer speaks of the agricultural resources of the Rocky Mountain region as follows:

> Generally speaking, those best acquainted with the West make the largest estimates of its resources and have the most faith in its future. Land, on first sight, often appears worthless, which experiment afterwards proves to be fertile. I instance the "Great Columbia Plains" of eastern Washington, where the soil, which varies from 1 foot to 20 in depth, is, except in the bottom-lands, a very light-colored loam, containing an unusually large percentage of alkalies and fixed acids. A few years ago sowing wheat on the soil would have been deemed throwing it away; but the experiment resulted in a revelation, viz, that these 14,000,000 acres of peculiar soil are probably the best wheat fields in all the world. Other illustrations equally striking might be given. * * * "

> The arable lands of the Rocky Mountains are mainly in the valleys, which, like basins, have gathered the detritus of the mountains for ages. The soil is therefore very deep and fertile, yielding much more than the same area in the East; and in the southwest two crops a year from the same soil are very common, so that this land is equal to twice or three times the same area in the East.

Another writes:

> Nothing is more surprising than the material for supporting a population which continues to be developed in all this region of mountain and plain, which twenty years ago was considered an inhospitable desert, capable of supporting nothing but Indians.

The State of Colorado, and the Territories of New Mexico, Wyoming, Montana, and Idaho, have collectively an area of 553,654 square miles, which is more than three times the area of the Middle and New England States.

The extraordinary mining development of this region and its immense grazing resources are widely known and appreciated, but its agricultural possibilities are, as yet, but little known to the general public. In some localities in the mountains, farming operations are carried on to a limited extent without the aid of irrigation, but such instances are exceptions to the general rule. For the growing of crops recourse must usually be had to artificial water-supply. The extensive irrigation systems, fully inaugurated in Colorado, and partially so in the adjacent territories, have already reclaimed for agricultural uses millions of acres once deemed barren and worthless. The only limit to progress in that direction will be the amount of available water. Could the sources of water supply be adequately protected, and storage reservoirs constructed in suitable places, thousands of square miles in this region could be gained to agriculture, homes provided for multitudes of people, and the aggregate wealth of the country greatly enhanced. The capacity of the land to produce crops and the fitness of the seasons to mature them are no longer unsettled questions.

NOTE.—More particular statements in regard to irrigation, as practiced in the Rocky Mountain region, are given in the descriptions of the several divisions as they occur in this report. The following summary will bring the whole matter into view at one glance, and on that account it has been inserted here. It will be understood of course that minute accuracy in such a case is impossible. Approximate estimates only can be made. But it is believed that the estimates are in no case exaggerated.

Colorado has from 900 to 1,000 miles of main irrigating canals, 3,500 miles of second class canals, and 40,000 miles of ditches, constructed at a cost of $11,000,000. More than 1,000,000 acres of otherwise useless land have thus been brought under successful and profitable cultivation.

Wyoming, in 1884, had seventeen incorporated irrigation companies, chiefly in two counties. One of these had under its control 60,000 acres of land, and has constructed a canal 66 miles in length. Another company has begun the construction of a canal calculated to irrigate 270,000 acres.

Utah, in 1885, had 2,810 miles of main and 7,750 miles of tributary canals, and 656,000 acres under cultivation by this means.

New Mexico is estimated to have irrigating canals and ditches equal in extent to those of Utah. Two canals are now projected capable together of watering from 3,000,000 to 4,000,000 acres.

In Idaho there are sixty-five land and water companies reported and there are many hundred miles of canals and ditches, but particulars are not published.

In Montana there is a considerable but indefinite amount of irrigation by means of the smaller mountain streams. One company in Yellowstone County has constructed a main canal 40 miles long and ditches capable of irrigating 60,000 acres, and another has a main canal 75 miles in length.

The intimate relation of the forests to the water supply necessary for irrigation will soon force itself upon the consideration of those living in the Rocky Mountain region, and it is well set forth in a recent statement of Mr. Nettleton, State engineer of Colorado, who says:

"It is estimated that 60 inches of water fall annually on the eastern slope of the Rocky Mountains in the form of snow and rain; 80 per cent. of this falls during the winter and spring months. That which falls late in the autumn and early in winter is most available for irrigation, as it becomes solid, almost like ice, and melts slowly under the summer's sun, affording a steady flow through the irrigating season. Snows falling in late spring melt rapidly, and the waters run down the rivers unused. Although about fifty mountain peaks in Colorado reach an elevation of over 14,000 feet, yet the snow nearly all disappears every season, small quantities only remaining in small patches here and there. On this account there are at present no glaciers in the Rocky Mountains. The cold mountains condense the moisture in the country adjacent, thereby robbing the plains of their quota of moisture.

"Hence the necessity for irrigation. It is quite easy to foretell the probable amount of water for irrigation purposes for the coming season by watching the amount of snow-fall in the mountains.

"Farmers living from 20 to 30 miles from the mountains, or where they can watch the snow-fall on the main range of the mountains, have learned to gauge their crops by the time the snow falls and the quantity. If the snow falls early, they expect water for late crops. If the snow falls principally in the spring months, they fear short water in summer and fall, and plant or sow accordingly.

"There can be no doubt about the influence that cutting or burning the timber on the mountains has on the flow of our streams. They will on this account become more intermittent in their flow, which is a drawback to the irrigation interests of the State. The preservation of the mountain forests should be encouraged."

INDUSTRIES.

AGRICULTURE.

Agriculture is making rapid progress in this region, and is likely to have greater proportionate development than other industries. Utah was the first of the mountain Territories to show adequately what could be done in the way of systematic farming, and the first to adopt proper methods of irrigation. Her example has been extensively followed, whenever practicable, throughout the region of the mountain and the plains. During the last year or two western Kansas and Nebraska and eastern Colorado have received large accessions of settlers who have opened new farms and grown crops without the aid of irrigation.

Except upon the plains, broad areas adapted to a single crop are not found. Great diversity of production exists by reason of differences in soil, elevation, and climate. Colorado Springs, the home of the writer, has an elevation of 6,000 feet above the sea. The spring seasons of the year are backward, and early vegetables, small fruits, and other supplies of a like nature are obtained in part from the warm valleys only a few miles distant but 1,500 or 2,000 feet lower in altitude. As the season advances nearly the same products are grown at higher elevations. Upon the farms of this region are raised wheat, oats, alfalfa, timothy, red and white clover, and other grains and grasses. In the orchards and gardens are found the hardier and smaller fruits, including many varieties of grapes. At elevations 1,000 or 2,000 feet higher in the mountain parks and valleys, or upon the Arkansas-Platte Divide, oats, rye, barley, buckwheat, potatoes, turnips, timothy, and other grasses, tame and native, are successfully cultivated; usually without the aid of irrigation. The foregoing is only an illustration of what is being done in many parts of the mountain region.

MINING.

The yield of precious metals for the year 1886 is officially reported as follows:

State or Territory.	Gold.	Silver.
Idaho	$1,800,000	$3,600,000
Montana	4,425,000	12,490,000
Colorado	4,450,000	16,000,000
Utah	216,000	6,500,000
New Mexico	400,000	2,300,000
Wyoming	(*)	(*)
Total in Rocky Mountain region	11,291,000	40,800,000
Percentage of total product in United States	32.4	79.5

* No report.

The copper product of the Rocky Mountain region is given in pounds as follows by Mr. Kirchhoff, jr., in the report of the mining statistics compiled by Mr. D. T. Day, of the U. S. Geological Survey:

State or Territory.	1882.	1883.	1884.	1885.	1886.
Idaho			46,667	40,381	
Montana	9,058,284	24,664,346	43,093,054	67,797,864	57,611,621
Wyoming	100,000	962,468			
Colorado	1,494,000	1,152,652	2,013,125	1,146,460	409,306
Utah	605,880	341,885	265,526	126,199	500,000
New Mexico	869,498	823,511	59,450	79,839	558,385
Total	12,127,662	27,944,862	45,477,822	69,190,743	*69,079,312
Total of United States	90,646,232	115,526,053	144,946,000	165,875,000	156,735,000
Percentage from Rocky Mountain region	13.3	24.2	31.3	41.7	44

* The decrease of production in 1886 was due partly to labor troubles and partly to unfavorable market conditions.

The lead product in 1886 for the region may be estimated as follows:

	Short tons.
Utah	20,000
Colorado	59,000
Idaho	16,000
Total	95,000

or about 75 per cent. of the total lead product of the United States.

Coal.—Statistics relating to the production of coal will be found in another part of this report.

STOCK-GROWING.

This industry has been not only a very important but a very profitable one. During the last year or two, owing to a variety of causes—mismanagement being a principal one—the leading branch of the business, cattle-raising, has not yielded much profit. The "range" system of raising cattle and horses, with its attendant cruelties and losses, is gradually giving way to more humane and thrifty methods. Improved breeds are being introduced, and no doubt in the near future the business will be placed upon a much better footing than heretofore. In fact, the immense grazing resources of the region are likely to be more fully utilized in the future than in the past.

The estimated number of cattle in the Rocky Mountain region at the beginning of the present year (1887) was 4,919,113, and the value of the same $104,981,067.

WOOL-GROWING.

This is a branch of the live-stock industry which should not be overlooked. In Colorado and New Mexico it has long occupied a prominent place, and it is gradually gaining ground in the surrounding Territories. Growing the mutton breeds of sheep is also receiving attention.

The number of sheep in the region now under review was estimated to be, on the 1st of January, 1887, 7,353,326, and their value $12,477,725.

MANUFACTURES.

Some of the leading manufactures are those connected with the mining industry, such as the reduction of ores, manufacture of coke, charcoal, machinery, and castings. Iron furnaces, steel and nail works; rolling mills, foundries, etc., are mainly centered at Denver and Pueblo.

The following is the product of the works of the Colorado Coal and Iron Company, at Pueblo, for the year 1886:

	Tons.
Coal	615,360
Coke	112,200
Pig-iron (five months' run only)	9,323
Spiegeleisen	982
Steel rails (four months only)	5,872
Merchant bar iron	4,240
Castings (for their own use only)	621
Cast-iron pipe	995
Nails, kegs of 100 pounds each	53,250
Track spikes, kegs of 150 pounds each	3,370

Smelting and reduction works are in operation in all of the principal mining districts. The many minor manufactures and productions of this country can not here be described. When one considers the extensive water-power afforded by the mountain streams, the inexhaustible coal measures, and the amount and variety of raw material at hand, it seems more than probable that the manufactures of the region will rapidly increase in number and importance. In view of the great production of wool here, it is difficult to understand why cloth and woolen factories have not already been established.

STONE AND MARBLE.

Extensive and valuable stone quarries have been developed and worked wherever building operations have created a demand for stone. The existence of many elegant and substantial public buildings, business blocks and residences, constructed of this material, attest the extent and value of this industry. Fine marble quarries of great extent have also been discovered at various points, and are receiving due attention and development.

POPULATION AND VALUES.

An estimate, based mainly upon official reports, of the present population of Colorado and the Territories under consideration is, in round numbers, as follows:

Idaho, 97,250; Montana, 130,000; Wyoming, 85,000; Colorado, 250,000; New Mexico, 148,000; Utah, 196,600; total, 906,850. The principal towns and their population are as follows:

Idaho.—Boisé City, 3,000; Hailey, 2,500; Ketchum, 2,000; Paris, 1,000.

Montana.—Helena, 10,000; Butte City, 15,000; Missoula, 2,500; Bozeman, 2,500; Fort Benton, Billings, and Miles City, about 1,500 each.

Wyoming.—Cheyenne, 7,700; Laramie, 5,100; Rawlins, 1,500; Evanston, 1,800; Rock Springs, 1,200; Douglas, 1,200; Carbon, 1,000.

Colorado.—Denver, 62,000; Pueblo, 12,500; Leadville, 11,000; Colorado Springs, 5,800.

New Mexico.—Santa Fé, 7,000; Albuquerque, 10,000.

Utah.—Salt Lake City, 20,768.

The following are the assessed valuations for the year 1887 of real and personal property, exclusive of mines:

Idaho	$20,741,192.00
Montana	60,200,000.00
Wyoming	32,089,613.00
Colorado	136,322,313.00
New Mexico	63,000,000.00
Utah	35,865,000.00

More detailed statements can be given as follows:

NOTE.—For the purpose of comparison, the estimates of the numbers and value of farm animals, January 1, 1887, made by the Statistician of the Department of Agriculture, are appended to the assessed valuations.

Assessed valuation of the Territory of Idaho for the year 1887.

Description of property.	Territorial estimate.	Estimate of Department of Agriculture.	
	Number.	Number.	Value.
Horses	132, 922	48, 750	$2, 681, 250
Mules		2, 436	210, 714
Cattle	442, 363	339, 453	7, 298, 240
Swine	60, 411	28, 100	147, 525
Grain (bushels)	2, 374, 325		
Hay (tons)	342, 914		
Railroads (miles)	900		

Total taxable property, $20,741,192.

Assessed valuation of the Territory of Montana for the year 1886.

Description of property.	Territorial estimate.		Estimate of Department of Agriculture.	
	Number.	Value.	Number.	Value.
Acres of land and improvements	4, 115, 457	$9, 898, 470		
Town lots and improvements	33, 954	8, 997, 460		
Horses	127, 748	4, 333, 595	129, 203	$6, 535, 088
Mules and asses	2, 121	116, 145	9, 229	662, 181
Sheep	968, 298	1, 952, 728	754, 681	1, 762, 197
Cattle	663, 716	13, 347, 815	812, 784	18, 775, 310
Swine	18, 837	75, 713	20, 263	119, 168
Wagons and carriages	10, 406	493, 716		
Watches and clocks	3, 619	90, 113		
Pieces of jewelry and plate	299	54, 646		
Musical instruments	1, 123	103, 971		
Shares of stock		288, 020		
Merchandise		3, 493, 976		
Capital and manufactures		296, 700		
Moneys and credits		5, 660, 843		
Household furniture		135, 827		
All other property		5, 737, 131		
Total		55, 076, 871		

Assessed valuation of the Territory of Wyoming for the year 1887.

Description of property.	Territorial estimate.		Estimate of Department of Agriculture.	
	Number.	Value.	Number.	Value.
Horses	66, 658	$2, 310, 712	82, 500	$3, 678, 675
Mules	2, 590	118, 300	2, 850	198, 887
Cattle	753, 648	10, 186, 360	1, 255, 298	28, 815, 365
Sheep	421, 688	637, 433	534, 020	1, 047, 480
Swine	1, 144	6, 010	2, 750	17, 596
Railroads (miles)	670			
Capital in manufactures and trade		1, 502, 700		

Total assessment, $32,089,613.

Assessed valuation of the State of Colorado for the year 1886.

Description of property.	State estimate.		Estimate of Department of Agriculture.	
	Number.	Value.	Number.	Value.
Acres of land with improvements	4, 534. 938	$24, 211, 001. 24		
Miles of railroad	2, 969. 03	23, 508, 367. 59		
Average of merchandise		6, 087, 084. 00		
Capital in manufactures		475, 926. 00		
Town and city lots		43, 779, 068. 00		
Horses	124, 032	4, 663, 327. 00	123, 770	$7, 178. 918
Mules	6, 247	385, 529. 00	8, 165	685, 224
Cattle	845, 038	12, 425, 061. 00	1, 070, 768	23, 768, 479
Sheep	777, 494	832, 121. 00	1, 149, 178	1, 845, 579
Swine	22, 260	67, 205. 00	21, 290	146, 424
Asses	2, 230	28, 203. 00		
Goats	10, 713	10, 639. 00		
All other animals	3, 421	26, 968. 00		
Musical instruments		339, 301. 00		
Clocks and watches		200, 391. 00		
Jewelry and plate		56, 612. 00		
Money and credits		2, 689, 646. 00		
Carriages and vehicles		900. 798. 00		
Household property		510. 985. 00		
Bank and other shares		1, 269, 836. 00		
All other property		1, 801, 640. 00		
Total valuation		124, 269, 710. 00		

To this may be added the mineral production, which is not taxable, as follows:

Gold	$4, 447, 077
Silver	14, 083, 190
Copper	43, 507
Lead	5, 143, 566
Total	23, 717, 340

More recent returns give the total assessed valuation of Colorado for 1887, as $136,322,313.36.

The changes from 1886 are mainly in the following items:

Description of property.	Number.	Value.
Miles of railroad	3, 650	$28, 988, 300
Horses	148, 027	5, 042, 480
Mules	7, 560	544, 865
Cattle	1, 500, 000	22, 500, 000
Sheep	1, 422, 900	3, 311, 652
Swine	63, 332	206, 292

Assessed valuation of the Territory of New Mexico for the year 1887.

Description of property.	Territorial estimate.		Estimate of Department of Agriculture.	
	Number.	Value.	Number.	Value.
Horses	....	....	20, 786	$745, 944
Mules	....	....	10, 912	520, 501
Cattle	916, 287	$11, 003, 280	1, 220, 968	21, 824, 801
Sheep	1, 702, 287	....	4, 025, 742	5, 958, 098
Swine	....	....	20, 990	131, 555
Coal (tons)	384, 762	....	....	....
Railroads (miles)	1, 050	....	....	....

Total assessment, $63,000,000.

Assessed valuation of the Territory of Utah for the year 1887.

Description of property.	Territorial estimate.		Estimate of Department of Agriculture.	
	Number.	Value.	Number.	Value.
Horses	250, 000	$10, 000, 000	56, 136	$2, 466, 490
Mules	....	....	3, 597	215, 082
Cattle	500, 000	11, 500, 000	219, 842	4, 498, 871
Sheep	2, 400, 000	7, 000, 000	658, 285	1, 343, 692
Swine	100, 000	500, 000	28, 656	237, 052
Railroads (miles)	1, 141	....	....	....

Total valuation, $35,865,000.

II.—THE FORESTS OF THE REGION.

LOCATION.

The forests of the Rocky Mountains, mainly coniferous, are usually located upon the mountain slopes, at altitudes varying from 4,500 to 12,000 feet above the sea; in some cases the timber line extends to a height of 12,500 feet. The foot-hills and mesas often have a scattering, inferior forest growth, and many of the streams which flow from the mountains are bordered with a sparse growth of cottonwood and a few other deciduous species native to the region.

AREA.

The forest areas, though large in themselves, are not large as compared with the area of the entire region, which amounts to 640,155 square miles, nor are they to any considerable extent contiguous. There are at present no means of determining accurately their bounds and extent. Approximate estimates only can be given, based mainly upon statements received from residents of the several localities, or from persons having special knowledge of particular portions of the region.*

According to the best data obtainable, and including in the estimate all kinds of forest growth, light and heavy, valuable and inferior, the approximate forest areas, in square miles, of the several divisions are as follows: Idaho, 15,990; Montana, 26,285; Wyoming, 12,060; Colorado, 16,625; New Mexico, 12,500; Utah, 6,000; or a total in round numbers of 90,000 square miles or 57,000,000 acres, being 14 per cent. of the total land area.

OWNERSHIP.

The bulk of the forest land of the Rocky Mountain region is still owned by the General Government. In New Mexico, through the means of old Spanish grants, the titles to large tracts of woodland are held by private parties. In Colorado, although the greater portion of the timber lands have been surveyed, comparatively a small part have become subject to private ownership. The lands selected from time to time by the State, under various grants from the United States, have usually been farming lands, including but little timber. The school sections, and a few other tracts owned by the State, embrace some timber land. It is difficult to determine the ownership of the forest lands in this State, to decide which belong respectively to the General Government, to the State, and to individuals. Although public surveys have been made, the field-notes and official plats give very limited information respecting the timber or forest growth; and since the surveys were made forest fires and operations incidental to lumbering, mining, and charcoal burning have effected very material changes in the timbered region.

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* It is one of the most difficult undertakings, as every one who has attempted it knows, to ascertain with accuracy the timber areas, especially in the great mountain region of the West. In all of the Territories I found a disposition among the people to overestimate the timber area, and to call all lands timber lands that had once been covered with forest growth. Lumber dealers and producers do not like to give figures to a Government agent, and when they do, are not likely to exaggerate them. There is no common and recognized standard by which to estimate forest areas.—E. T. E.

In Wyoming, Montana, and Idaho, in all of which large forests exist, hardly any of the timber lands have been surveyed. It is gratifying to know that the present policy of the General Land Office is to discourage or forbid the making of such surveys. The precedent is a good one, as tending to prevent encroachment upon the forests.

FOREST CONDITIONS.

The Rocky Mountain region embraces a wide expanse of wooded ranges, foot-hills, valleys, parks, and plateaus. Naked and often snow-clad crests and peaks, rocky slopes, barren surfaces, deep defiles, and swift-rushing streams still further diversify a landscape wonderful in the extent and variety of its natural features.

Upon the mountain ranges are irregular masses of coniferous forest, separated by wide spaces—the latter treeless, or sometimes clothed with a growth of Aspen. Bordering the streams are Cottonwood, Willow, Alder, and other deciduous growths of minor importance. The "parks" (by which are meant mountain valleys bare of timber or nearly so) are usually covered with wild grasses or sage-brush. Scrub-oak and Cedar, Sage-brush, and other shrubs—in rare cases a scattering growth of timber—are found in the foot-hills, mesas, and plateaus.

This region, though nearly surrounded by arid or semi-arid plains and plateaus, and subject, more or less, to conditions of aridity, heat and cold inimical to forest growth, receives in many parts a comparatively large precipitation of moisture, and is favored through large portions of the year with abundant sunshine. To these last-named causes may be ascribed the existence here of relatively extensive forests. It is believed that but for the scourge of fire, these forests would be at least one-third greater in extent.

Upon the western slope of the main range the annual rain and snow-fall are greater than upon the eastern side; hence the larger and more important forests are found there. Furthermore, the forests of that portion have suffered less from fire and depredation than those in other sections. In all parts of the mountain region, northern slopes are the most favorable to forest growth, as affording maximum conditions of moisture and minimum evaporation.

The soil in which these forests grow consists, for the most part, of decomposed rock (or gravel) mingled with sand. A thin surface layer of humus aids, ordinarily, in the retention of moisture, but in dry seasons it is a source of danger, promoting the spread of fire.

The surface is usually quite sloping—in many cases extremely so—and the soil, deficient in clay or other coherent substances, is easily moved by the action of water. When, therefore, the slopes have been stripped of their natural covering, the violent rain storms of the region have a powerful and disastrous effect upon them. The light surface mold is carried downward to the valleys, more or less remote, and is soon followed by masses of sand and gravel. The mountain side, which was formerly clothed with a noble forest, now seamed and furrowed by the torrents, has become a barren waste—beyond reclamation. Conditions identical with these are very apparent along the front range in Colorado, and in many parts of the mining districts throughout the mountain region.

Even in the most favored districts, where the forests have been removed their renewal is extremely difficult. Nature does much in such cases, however, and though the original species may not be reproduced, an inferior growth often appears. The extent of natural reforestation varies greatly in different localities. In New Mexico, with greater degrees of heat and aridity than prevail farther north, the second growth is proportionately less vigorous. Where fierce forest fires have scorched the ground and destroyed the vegetable mold, the difficulty of reforestation is usually greatly enhanced. On the other hand, it is alleged that in some instances the action of fire serves to open the cones or outer coverings of certain tree seeds, and thus affords them a chance to take root and grow. It has been said, also, that the ashes produced by a forest fire enriches the soil, and to that extent promotes the reproduction of trees. But these are at best only mitigating facts, if they are facts, attending the almost inestimable loss resulting from forest fires.*

In what has been said above concerning reforestation, reference has been made to spontaneous growth. While the necessity is great for restoring to the denuded slopes of the Rocky Mountains their once useful and beautiful forest covering the expediency of attempting the artificial planting of large tracts in that section is doubtful. If men will cease their destructive operations and extend a protecting hand over the forest regions, nature will repair in a measure the injuries of the past. In truth, most kindly healing processes are already begun. The ubiquitous Aspen, with its light summer foliage and brilliant autumn hues, gives grateful shade and moisture to wide areas which otherwise would be barren and desolate. Some abler pen than mine should apostrophize the Aspen! It is nature's restorative—the balm poured upon grievous wounds! No soil, apparently, is too poor and inhospitable to provide for it. It has, however, its limitations. It is a denizen of the mountains, and succumbs to excessive degrees of heat and aridity. The Dwarf Maple, Creeping Juniper, Wild Rose, and other hardy shrubs are also helpful in the restoration of denuded surfaces.

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* These are facts only in the imagination of those who wish to find an excuse for the unmitigated nuisance of forest fires. No cones need the action of fire to be opened; a sufficient quantity would be opened by the heat of the sun, without destroying the seeds, as the fire does. No trees need the enriching quality of the ashes, but their seeds do need very much the vegetable mold, as a bed in which to germinate and to be supplied with the needful moisture which the mold provides, but which the ashes are not capable of storing up.

The fires, not only of this year, but those of years back, have destroyed the chances of natural reforestation by seed in many places, because they have destroyed the proper seed-bed.—B. E. F.

In the midst of these minor growths the seeds of the Pine, Spruce, and other timber trees gain lodgment and find necessary protection.

In all situations where the existing conditions of soil and climate are favorable the planting of forest trees should be encouraged to the utmost extent. In valleys, among the foot-hills, upon the mesas and plains where water is available, and along the streams, irrigating canals and ditches, this important work should be carried on.

There is no longer doubt that with the aid of irrigation, trees can be made to grow at any point upon the western plains. Nay, with a proper selection of species and judicious treatment, it is probable that plantations and forests can be established even without the aid of irrigation.

FOREST FLORA.

The forests of the Rocky Mountain region are mainly coniferous, with scattering groves of Aspen in the mountains, Scrub-oak and Cedar upon the foot-hills and mesas, and Cottonwood, Box-elder, Dwarf Maple, Birch, Willow, and other minor deciduous species along the canyons and streams.

A full account of the woody plants prepared by Mr. George B. Sudworth will be found on page 153 of this report. The more important forest trees occurring in each Territory are also enumerated in the special part of this report.

LOCAL DEMANDS ON FOREST SUPPLIES.

By numerous letters of inquiry sent to lumbermen and others, in various localities, efforts have been made to obtain statistics relative to the consumption of timber in this region. The results, however, have not been commensurate with the efforts, and the information so obtained has been quite meager, and shows mostly how little thought or intelligent estimation has been so far given to this important branch of economics; how little its importance is as yet appreciated.

One of the questions contained in the letters of inquiry was as follows:

Is there danger of the timber supply failing?

To this, twelve replies in the affirmative were received and nine in the negative. Five correspondents stated there was no danger of the supply failing unless the timber was destroyed by fire, and that the undergrowth would make good the loss by consumption, and one stated that the timber would last for a hundred years.

With respect to remedies for failing lumber supply, the following suggestions were offered:

Import from Oregon.
Ship more lumber from the East.
Protect from fire.
Post notices to prevent setting of fires.
Encourage tree planting.
Plant Oak, Walnut, and Hickory.
Impose heavy penalties for cutting small timber.
Timber should be owned by private parties.

The principal uses made of timber in this region are the manufacture of lumber, railway ties and timber, mining timber, telegraph poles, charcoal, fencing, and fuel.

LUMBER.

Yellow Pine (No. 7),* White Pine (No. 2), and Black Pine (No. 9), White (Engelmann) Spruce (No. 11), and Red or Yellow Fir (No. 19), are the principal timber trees of the region. They furnish most of the common and a portion of the finishing lumber. Considerable White Pine (*Pinus strobus*) from the lake region, Redwood (*Sequoia sempervirens*) from the Pacific coast, many of the hard woods also, and Southern Pine are imported for the finer kinds of work.

Approximate estimates, based upon reports received from some of the principal lumber dealers of the region, make the consumption of lumber for the year 1886 as follows: Native, 46,000,000 feet, B. M.; imported, 18,000,000 feet.

NOTE.—These figures can hardly be used to convey an idea of the quantities of lumber manufactured at home or imported into the region, and unless the large but quite uncertain quantity of unsawn lumber used in the mines is deducted, they seem to be far below the actual amounts used, as will appear from the following results of an independent canvass among saw-mill men and statements of railroad companies.

From these an estimate of between 150,000,000 and 200,000,000 feet of native timber and of 40,000,000 to 50,000,000 feet imported would appear to represent more nearly the amount of lumber consumed in the region.

Idaho.—Five mills out of six report an aggregate cut of 4,550,000 feet, while an estimate places the whole amount of native timber used in the Territory at 17,000,000 to 19,000,000 feet. (See also page 93.)

Montana.—Nine mills out of eleven report an aggregate cut of 19,592,000 feet, mainly for mine timber, but exclusive of railroad ties and cord-wood, of which large quantities are cut.

Wyoming.—Only one mill out of five reports cutting 500,000 feet, and estimating the cut for the Territory at 8,000,000 feet outside of railroad and mine timber.

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* The numbers refer to those used in the account by Mr. Sudworth in this report.

Utah.—Out of five mills replies were received from two, with an aggregate cut of 1,350,000 feet; one estimates the cut for the Territory at 10,000,000 cubic feet of mine timber and 60,000 cords of fuel and fencing.

This estimate assumes that the cut in Wahsatch and Summit Counties, which is placed at 2,000,000 feet B. M. lumber, 300,000 cubic feet mine timber, and 12,000 cords fuel and fence material, represents 20 per cent. of the total cut of the Territory.

Colorado.—Out of some eighty mills written to, of which several have gone out of business, thirty have replied, reporting an aggregate cut of 18,820,000 feet for the year 1886. From various estimates by counties, the total cut of mill timber can not be short of 75,000,000 to 100,000,000 feet, of which 25,000,000 are used in Lake County (Leadville) alone.

No replies from New Mexico. (Estimation, see page 141.)—B. E. Fernow.

NOTE.—We are indebted to the kindness of Mr. E. R. Murphy, auditor of the Denver and Rio Grande Railroad, and of Mr. J. A. Munroe, general freight agent of the Union Pacific Railroad, for the following interesting statements regarding the movement of lumber and other wood from outside points to the Rocky Mountain region.

Union Pacific Railroad.—The total amount of lumber hauled into the Rocky Mountain region from points on the line of this road was, in 1886, 53,786 tons (33,616,250 feet, B. M.), and during nine months of 1887, 65,437 tons (40,808,125 feet, B. M.). Of this amount 24,595 tons (15,371,880 feet), or 45 per cent., were from Oregon in 1886, and 40,918 tons (25,573,750 feet), or 60 per cent., from Oregon in 1887.

Denver and Rio Grande Railroad.—As appears from the following detailed statement, this road during the same period imported 1,075 tons (672,422 feet, B. M.) in 1886, and 625 tons (390,000 feet, B. M.) during nine months of 1887.

Shipments of lumber and wood over Denver and Rio Grande Railroad to Rocky Mountain region from points outside.

From	1882.	1883.	1884.	1885.	1886.	1887 to August 31.	Total, 1882 to August 31, 1887.
	Pounds.	*Pounds.*	*Pounds.*	*Pounds.*	*Pounds.*	*Pounds.*	*Pounds.*
Denver	2, 844, 300	2, 934, 340	802, 900	808, 075	787, 090	961, 240	9, 137, 945
Colorado Springs	20, 000	17, 000					37, 000
Pueblo	648, 000	280, 055	550, 090	277, 635	506, 545	88, 390	2, 350, 715
Florence	14, 800	16, 000		20, 000	20, 000		70, 800
Canon	82, 000	48, 000	32, 000	17, 300	37, 055		216, 355
Barnes						40, 000	40, 000
Apishapa	149, 475	108, 000	124, 700	300, 000	645, 710	160, 000	1, 487, 885
El Moro		53, 300					53, 300
Santa Clara				101, 650			101, 650
La Veta	235, 000	232, 000	320, 000		155, 350		942, 350
	3, 993, 575	3, 688, 695	1, 829, 690	1, 524. 660	2, 151, 750	1, 249, 630	*14, 438, 000

* Or 4,512,000 feet.

RAILWAYS.

With the exception of forest fires, it is conceded that no one agency consumes the forests of the country so rapidly as do the railways. Their lines, of vast extent, stretching in every direction, make enormous and unceasing demands upon the forests, and it is quite time for the railroad corporations, as well as for the public, which must suffer by any impediments to cheap railroad transportation, to interest themselves in a better management of forest supplies.*

While it is true that railroad companies legitimately require large quantities of timber, it is not less true that in many cases they use the timber resources of the country in a most wasteful and destructive manner. Perhaps the most constant and serious drain on their part is in connection with the demand for cross-ties. For this use it is customary to cut the smaller and rapidly growing trees, which results in a wasteful consumption of the trees themselves and a great diminution of the source of future supply; or else much valuable timber is left in the woods, the tie cutter taking only such parts of trees as will most easily yield him ties of the required size.

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* See Bulletin No. 1, Department of Agriculture, 1887, Forestry Division, on the relation of railroads to forest supplies, with appendices.

The information collected with respect to the railway mileage of this region, and the amount and kinds of native timber used by the several roads, is not sufficiently complete to warrant the presentation of the same in tabular form, and is therefore embodied in the condensed statements following.

By the courtesy of Messrs. Poor, publishers of Poor's Manual of Railroads, we are enabled to give, in advance of publication in the usual way, the following estimate of the railroad mileage in the Rocky Mountain region at the present time. In a letter received from them they say:

> From careful examination of the data now in our office, our estimate is as follows

	Miles.
Idaho	850
Montana	1,575
Wyoming	850
Colorado	3,650
New Mexico	1,238
Utah	1,145

> It is possible that before the end of this year there will have been added to the mileage of the six States and Territories named an additional 300 miles of new railroad, making the total increase for the year about 1,650 miles of railroad, to which will be added at least 400 miles of sidings and other auxiliary tracks, or a total of over 2,000 miles of track within the year.

Assuming this estimate to be correct, there will be in the Rocky Mountain region at the close of the year 1887, 10,008 miles of railroad track. This would bring the demand upon the forests up to the present time for construction to not less than 200,000,000 cubic feet, and the annual demand for renewal and maintenance to 25,500,000 cubic feet.

Union Pacific Railway.—Consumption of native timber. Statements from S. T. Smith, general superintendent, Omaha. (Length of road in Colorado, 965 miles.)

August 20, 1886. We have used during the last twelve months in Colorado about 200,000 cross-ties, about 5,000 posts, 2,700 cords of slabs for fuel purposes, and 1,500,000 feet of mountain pine for various purposes.

February 1, 1887. Number of cross-ties and feet of dimension lumber used in the year 1886 on the following divisions:

State or Territory.	Number of cross-ties.	Square feet of dimension timber.
Idaho	9,180	1,084,827
Montana	41,844	401,221
Wyoming	355,930	1,800,282
Colorado	279,827	5,164,639
Total	686,827	8,450,969

Denver and Rio Grande Railway.—Mileage of road and consumption of native timber. Statement from C. M. Hobbs, purchasing agent. (Length of road, main line, in Colorado, 1,161.8 miles; New Mexico, 155.2 miles; Utah, 368 miles.)

Approximate amount of timber required for annual renewals and repairs:

Cross-ties	number..	1,023,376
Sawed timber (B. M.)	feet..	5,625,000

Kinds of timber preferred for the several purposes:

For cross-ties, Red Spruce (local name for White Spruce) and Yellow Pine—the former very much preferred; for bridge timbers and cars, Yellow Pine; for buildings, Yellow Pine or Red Spruce.

Native timber used in Colorado and New Mexico in the year 1886:

Number of broad-gauge cross-ties	60,000
Number of narrow-gauge cross-ties	740,000
Feet of dimension lumber (B. M.)	3,000,000

In my opinion there is an ample supply of timber in our State for a hundred years to come; but the increasing cost of securing it will soon make necessary the use of some wood-preserving process, at least on the part of railroad companies.

Colorado Midland Railway.—Mileage of road and consumption of native timber. Statement of H. D. Fisher, president of Colorado Midland Construction Company.

January 27, 1887. The present mileage of the Colorado Midland Railway, now under construction, and which we expect to finish and operate before the close of the year, is 250 miles.

The number of cross-ties required for the above main track and the sidings requisite for the same will be about 900,000.

The amount of timber to be used in bridges and other construction work is estimated at between 6,000,000 and 7,000,000 feet.

The timber generally used for bridge purposes is Yellow Pine or Red Spruce (local name for White Spruce); and the same may be said with regard to ties, except that we endeavor to obtain all the Red Spruce that can be had.

Burlington and Missouri River Railroad.—Statement from G. W. Holdrege, general manager, of date January 22, 1887. (Length of road in Colorado, 175 miles.)

No Rocky Mountain timber used in 1886.

Atlantic and Pacific Railroad Company.—Consumption of native timber during the year 1885. Statement from D. B. Robinson, general manager.

During the year 1885 we consumed in New Mexico 937,240 feet, and in Arizona 2,028,959 feet (B. M.) of native pine. Our principal source of supply is from the Ayer Lumber Company, at Flagstaff, Ariz. Pine lumber is about the only kind of lumber we use, and is the only kind that grows either in Arizona or New Mexico to any extent.

Mileage of road in New Mexico and consumption of native timber during the year 1886. Statement from T. R. Gabel, general superintendent. (Length of road in New Mexico, 191 miles.)

Number of cross-ties (native pine) used in New Mexico in the year 1886, 47,456.

Number of feet of dimension lumber (native pine) used in New Mexico in the year 1886, 298,755.

On the western division of this road extensive use has been made of Redwood for cross-ties and telegraph poles; these ties last about twelve years.

TELEGRAPH POLES, ETC.

The consumption of native timber, especially the White Spruce, for telegraph and telephone poles, amounts in the aggregate to considerable. In a recent communication received from the superintendent of the Western Union Telegraph Company, at Omaha, Nebr., he says:

> We are not now using any native poles, but, for what renewals are made and new lines built white Cedar poles are shipped from the East—obtained mainly in Michigan and Ohio. In the lines built several years ago pine was used.

The superintendent of the Colorado Telephone Company at Denver states that telegraph and telephone poles should be cut in winter, when the trees are not full of sap. Experiments in applying preserving processes for poles, tarring, charring, etc., have not been satisfactory. The nature of the soil greatly affects durability. There exists also this practical objection, that as contracts provide that poles shall be delivered "at the stake," for lines of considerable length preserving processes are not feasible.

MINING.

In connection with the mining industry in this region, a great amount of timber is annually consumed, of which it is impossible to give even an approximate estimate. But it is larger in the aggregate than one unacquainted with the facts would suppose. One mining camp in Montana, Butte City, established only a few years, it is estimated requires at its present state of development not less than 40,000,000 feet, B. M., per year, of round and square timber of large size, not to speak of the countless number of small trees used for "lagging." Much of the timber used in Utah and Montana is now imported from the Pacific slope, as the home supply of good-sized or accessible timber, especially in the former Territory, has been exhausted, or timber can be produced more cheaply by rail from a distance. Much timber is required for fuel and charcoal, especially the latter, which is used extensively in smelting operations. The before-mentioned mining camp with its reduction works consume, it is estimated, 1,000 cords of fire-wood a day, or about 30,000,000 cubic feet of solid wood per year.

CHARCOAL MANUFACTURE.

From the best information obtainable, it is believed that the charcoal burners of the Rocky Mountain region are doing immense injury to the forests. They draw their supplies of wood almost wholly from the public domain, and although they profess to make large use of dead timber, there is no doubt that the growing forests are largely encroached upon by them. A person well informed upon this subject recently expressed himself thus:

> The charcoal burner is the most conscienceless violator of law that we have, cutting everything down to poles 2 inches in diameter. He leaves behind him barrenness and desolation. The traffic in charcoal is so exhaustive upon the forests, and so injurious to the best interests of the State, that wherever permitted it should be done under a license only, by the giving of a bond, and by the rigid enforcement of conditions and penalties. There are no reasons why the charcoal burner should longer be allowed to prey upon the timber and young forest growth. On the contrary, many strong and urgent reasons exist for limiting his operations.

Efforts were made to obtain statistics relative to the consumption of timber for the manufacture of charcoal, but, as in the case of lumber manufacture, the returns were quite unsatisfactory.

In response to the question, "What is your principal source of timber supply for the manufacture of charcoal?" replies were received (mostly from persons in Colorado and New Mexico) as follows:

In the foot-hills; plenty of pine and piñon.
Foot-hills and ranches.
Purchase from parties who deliver at kiln.
All around the city (Breckenridge, Colo.).
Patented lands and pre-emptions.
Mineral ground.
Abundance of timber, chiefly on grants (N. Mex.).

To the questions, "What kinds of timber do you mainly use? What proportion of green timber and what proportion of dry?" the following replies were received:

Pine and piñon.
All dry wood—it takes too long to burn green.
One-fifth dry; piñon the best for charcoal.
Piñon; mostly dry—killed by fire.
Pine; 90 per cent. dry, 10 per cent. green.
Aspen; three-fourths green, one-fourth dry.
Pine; one-half green, one-half dry.
Piñon; equal parts of green and dry.
Scrub timber; half dry and half green.
Dead timber and dry; green too expensive.
Piñon, pine, and cedar; one-third green, two-thirds dry.
Pine; 75 per cent. green.

Concerning the yearly product of charcoal (in bushels) reports were received as follows:

Colorado:	
Lake County	2,000,000
Conejos County	150,000
Custer County	150,000
Rio Grande County	150,000
Park County	800,000
Dolores County	75,000
Chaffee County	380,000
La Plata County	75,000
New Mexico:	
Santa Fé County	200,000

No means are at hand for verifying the above statements; and besides, it will be seen that the figures cover but a small territory. The Philadelphia smelter at Ketchum, Idaho, has thirty kilns for burning charcoal; the annual product is not reported.

At least nine-tenths of the charcoal manufactured is used by the smelters; the remainder is used mostly by blacksmiths and tinsmiths.

A Colorado manufacturer writes as follows upon the subject:

> The largest amount of charcoal is made and used in Lake County; the Leadville smelters there use daily about 10,000 bushels. Charcoal is made of both dry and green timber. About three-fourths is made from dead timber, one-half of which is down. One cord of wood will yield about 50 bushels of coal. Dry or dead timber, if sound, will yield more than green, but the quality of the coal will be about the same.*

Concerning the extensive use of charcoal by smelting companies, and the consequent heavy draft upon the forests, it is reliably stated that the use of charcoal in smelting is a convenience but not a necessity. There is in many parts of this region an abundant supply of mineral coal, of good quality, including dry, bituminous, or coking, and anthracite, and its use by smelting companies would simply involve the employment of more skillful furnace men than are used under the present system.

FENCING.

Although barbed wire is largely superseding the use of boards for fencing, there is a continued demand for timber for fence posts, rails, etc., and as farms and ranches are rapidly increasing in number, the demand for fencing material is likely to grow in proportion. Much dead timber is utilized in this way. In the mountains, Aspen is often used for fence rails. For posts, Yellow Pine (here called Pitch Pine), Cedar (*Juniperus*), White and Black Spruce, etc., are used. In a few instances posts for wire fences have been made of bar iron.

With the data available, it is impossible to state the amount of timber that is annually consumed in this region for fencing purposes. It is a varying and probably an increasing quantity.

FUEL.

In the mountains, except in the immediate vicinity of coal mines, wood is the principal fuel, and for this dead and fallen timber is largely used. Except in the case of Piñon, it is unlikely that growing timber will suffer greatly from this use, and the greater portion of the Piñon meets its fate at the hands of the charcoal burners. In most of the towns, and in the plains region, mineral coal is furnished of good quality and at reasonable prices.

NOTE.—Since the fuel question is a most important one in connection with forest preservation, the statistics of the supply of mineral coal are of great interest in this place. The following notes, therefore, taken from the reports of the Division of Mining Statistics and Technology, U. S. Geological Survey, are here inserted.

In the Rocky Mountain district coal beds are found in a number of geological formations, from the Carboniferous up to and including the Cretaceous.

No detailed information of the entire coal area of the Rocky Mountain region, similar to that which has been determined by State geological surveys of the coal basins east of the Rocky Mountains is available, and no reliable estimates have been made of the areas underlaid by workable coal beds. It has been surmised that the total area of the coal-fields of this district is between 200,000 and 300,000 square miles, but this estimate is little more than a guess.

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* From imperfect returns to a separate canvass, it would appear that the total consumption of charcoal for smelting purposes in the region must be placed at round 4,000,000 bushels, of which the three Leadville smelters take 2,364,000 bushels.—B. E. F.

The total production, exclusive of colliery consumption, in each State and Territory, and corresponding value at the mines in 1886, are shown in the following tables:

States and Territories.	Total production not including colliery consumption.	Value of coal at mines.
	Short tons.	*Dollars.*
Colorado	1, 368, 338	3, 215, 594
Wyoming	829, 355	2, 488, 065
New Mexico	271, 285	813, 855
Utah	200, 000	420, 000
Montana	41, 846	174, 460
Idaho	1, 500	6. 000
Total	2, 720, 324	7, 117, 974

In the Rocky Mountain region the production of coal is dependent exclusively upon the demand of the local trade. This varies not only on account of the growth and decline of the local industries, but upon the variable freight tariffs which have permitted the importation to Rocky Mountain points of more distant and superior coals at prices advantageous to the consumer.

Colorado.—The general prosperity of Colorado in 1886 has in no way been better shown than in the great development of the coal-fields of the State, although this development was begun too late to show a very great increase in the production for 1886 over 1885. While the mines in the northeastern portion of the State have only held their own, those of southeastern Colorado have materially increased their output in response to the steadily increasing demand from points in western Kansas and Nebraska. The greatest amount of new work has been done, however, west of Pitkin and the Continental Divide, in what is known as the Glenwood field.

Noteworthy discoveries of coking coal have also been made in Gunnison County, on Ohio Creek, and of anthracite of good quality, in a region where its existence has only been suspected—the basalt-covered tract southwest of Hahn's Peak, in Routt County. The more remote coal-fields, although known to produce excellent coals of varying qualities, have been hitherto neglected, because of the remote prospect of railway communication, which is necessary to bring their product into competition with that from well-opened mines.

The great activity in railway building in the direction of Garfield, Routt, and Pitkin Counties has spurred on the work of opening the coal beds in these counties, in order to meet the demand which the completion of the three railways now being built in that direction will bring. The superior quality of the coke made from the coal from the mines in Pitkin and Garfield Counties, and the accessibility, low altitude, and thickness of the beds in the anthracite districts of Routt County will meet a commercial demand from the smelting and manufacturing centers of Colorado, and also from those in the adjoining States and Territories.

Total product of mines operated in the interest of railways in Colorado for 1886 was 1,115,267 tons; increase of 0.7 per cent. over 1885. The increase in railway production is very slight indeed. The coal area has been variously estimated at from 20,000 to 50,000 square miles. The known and partially developed coal-fields cover about 1,000 square miles, while the area of the Laramie, Fox Hills, and Colorado cretaceous formations, which are coal-bearing, comprises about one-third of the surface of the State, or approximately 35,000 square miles.

The coal production of Colorado in 1876 was 117,666 short tons, as against 1,368,338 short tons for 1886 and 1,791,735 tons in 1887.

The average number of men employed, directly or indirectly, in the coal mines of Colorado is estimated at 3,500.

The State inspector estimates that the average thickness of the coal beds worked in Colorado is 5 feet 3⅗ inches. He also states that the thickest bed worked is 9 feet and the thinnest is 2 feet.

The average price paid for mining and loading the coal and doing the necessary timbering is 89 cents per ton of 2,000 pounds of screened coal.

The average cost of the coal delivered on the cars is $1.74 per ton.

The average value of the coal is estimated at $2.35 per ton, making the total product of the State worth $3,215,594.30.

Idaho.—Large areas exist in the Territory underlaid by bituminous coal and lignites. Mines have been opened at Smith's Fork and on Twin Creek, and what is known as the Mammoth bed shows local thickness of 70 feet.

A good quality of lignite has been found near Boisé; also on the Snake River, between Payette and Weiser City. A good blacksmithing coal is also reported on Sucker River, 22 miles north of Silver City; also several deposits near Lewiston, in the northern part of Idaho.

Montana.—Much interest has been taken of late years in the coal-fields of Montana and the development of the coal and lignite beds.

Although the occurrence of good fuel in Montana is a matter of great importance to the development of the Territory, there has been no great activity displayed in coal mining in Montana during 1886. The greatest production had been at the Timberline mines, between Bozeman and Livingston, but the production there was seriously interfered with by labor troubles, as a result of which the mines were closed in July, and no coal was produced during the last six months of the year.

The value of the Territory's output in 1886, at $3.50 per ton, was $174,460. The number of men employed can not well be estimated.

New Mexico.—There were no special developments in the coal-mining industry of New Mexico in 1886. The field of the largest operations has shifted from Raton to Gallup and other points near by on the line of the Atlantic and Pacific Railroad in Bernalillo County, and near the Arizona border.

No new mines have been opened. The production of the Raton district fell from 135,833 tons in 1885, to 87,706 tons in 1886. This fall in production was due mainly to the increased production of better coal at the Starkville and Rockvale mines in Colorado, which furnished the Atchison, Topeka and Santa Fé Railroad with coal for shipment and for railway uses. The coal from Raton is used almost exclusively for fuel by the Santa Fé Railroad. The mines are located within the Maxwell land grant, and it is understood that a royalty is paid.

A large amount of the San Pedro coal is coked, the coke being used by smelting works in New Mexico and Arizona.

Wyoming.—The coal-fields of Wyoming are of great extent and value. They have been known since 1850, but remained undeveloped until the completion of the Union Pacific Railroad to Carbon, 100 miles west of Laramie, in 1868. The Coal Measures are estimated to cover at least 20,000 square miles of the surface of Wyoming, and the beds are found for nearly 350 miles along the line of the Union Pacific Railroad, in every case, where developed, cropping boldly on the surface. In quality, the coal is a lignite of superior grade, and suitable for all heating and domestic purposes, but non-coking and useless for gas making.

The entire coal-fields of Wyoming are practically controlled by the Union Pacific Railroad. The capacity of these beds is indefinite. They would doubtless be able to supply the whole demand of the far West with a uniformly good coal.

The total amount of coal mined in that region in 1875 was 300,808 short tons, and in 1885 it was 807,328 short tons.—B. E. Fernow.

DESTRUCTIVE AGENCIES.

FOREST FIRES.

In nearly all portions of our country fire is the most destructive agency affecting the forests. It does immense harm in the Rocky Mountain region. Annually, during the dry seasons, forest fires break out, spread with great rapidity, and destroy in a few days the growth of many years. The aridity of the climate, the resinous nature of the timber, the prevailing high winds, and the sparseness of population render forest fires in this region almost uncontrollable. They are doubly disastrous here, for when the mountain slopes are denuded of their natural covering, restoration is extremely difficult, if not impossible.

The following is taken from the recent report (1886) of Hon. S. T. Houser, governor of Montana, to the Secretary of the Interior:

> Another loss that has been greatly increased this year by the extended drought is the fearful destruction of our mountain forests by fires. These fires occur every summer. They originate generally from carelessness of hunters and campers (white or Indian), sometimes from lightning. In former years the destruction has been comparatively limited. This season they have prevailed generally, covering immense districts. More timber has been destroyed in the past six months by fire than would supply the wants of our people for fifty years, and more than will be renewed by growth in a generation.

By the enactment of laws prescribing penalties for the willful or careless setting of fires, and requiring the local authorities to post notices warning persons against violation of the law, some good has been accomplished. It is evident, however, that effective measures for the prevention of forest fires will not be adopted until the people and law-making powers become fully alive to their necessity. And then the object can be effected only by a carefully devised system of forest protection which will include the active co-operation of local officers.

Acres burned and values destroyed in Rocky Mountain region in 1880.

States and Territories.	Acres.	Value.
Montana	88, 020	$1, 128, 000
Idaho	21, 000	202, 000
Wyoming	83, 780	3, 255, 000
Utah	42, 865	1, 042, 800
Colorado	113, 820	935, 500
New Mexico	64, 034	142, 075
Total	413, 519	6, 705, 375

WASTE.

The wasteful methods now practiced in dealing with our timber supplies deserve earnest condemnation and, by the enactment of proper laws, should be visited with severe penalties.

In some instances lumbermen will set mills near large bodies of fine timber, and with unrestrained greed cut down vastly more timber than they can use. Again, it is the common practice to use the butts or larger portions of the trees for sawlogs, while the limbs and smaller parts of the trunk are left to waste and to furnish food for forest fires. In districts where large-sized trees abound it is not unusual, on the other hand, for tie choppers to cut ties from the upper and smaller portions only, and leave the butts on the ground to decay.

Any laws or customs which allow the cutting of trees and the utilization of a portion only, or permit the cutting of partly-grown trees (except in forest reserves or plantations, for necessary thinning) are pernicious, as authorizing wasteful and improvident methods.

SNOW AND LAND SLIDES.

Snow-slides are frequent in the Rocky Mountain region, more especially among the higher Colorado ranges. They usually occur in the late winter and early spring months, when heavy falls of snow are succeeded by sunshine, causing the partial melting of the snow, and giving it also great weight. The slides or avalanches destroy both life and property. In some instances entire mining camps have been engulfed. Slides often start near the crests of the mountains, above the timber line, and gaining momentum as they descend, carry every thing before them. Large trees are swept away, rocks of many tons weight are torn from their beds, and human beings who are in their path are entombed in the snow, which packs like ice, yielding only to the axe and pick. Again, the impacted snow, after reaching the bottom of a deep gulch, will be forced sometimes far up the opposite side, carrying with it buildings, people, and whatever may be in its way.

Land-slides, though not frequent, some times occur. Through the action of frost, melting snows, or rain-fall—or all combined—masses of earth and rock are precipitated down the mountain side, overwhelming all beneath. To a beholder, the mass, with its accompanying roar, smoke, and fire, would seem to have evoked the lightnings and thunder to aid it in its destructive course. The path of the slide is usually marked by a strip of naked rock—of greater or less breadth—called, in mountain parlance, a "gouge," and upon which soil or vegetation is not likely to appear again. What means, if any, can be devised for the prevention of these disasters it is hard to say. Stripping the timber from the slopes, if not an original cause, contributes largely to the evil effect. Land-slides would hardly be possible in localities where the soil is sustained by the interlacing roots of a vigorous forest growth. It has been stated that in some of the Alpine regions stakes are driven upon the upper slopes of bare mountains to prevent the inception of snow-slides. Such a plan would hardly be feasible here, as the higher slopes of our mountains present steep and rocky surfaces of immense area.

NOTE.—It is a well-known fact that in Europe, not only torrents but land-slides as well as snow-slides are induced and aggravated by the removal of the forest cover, but also that their formation has been prevented by reforesting and returfing the denuded mountain slopes. If in the Rocky Mountains the occurrence of these dangers is not so frequent and disastrous as it has proved to be in Switzerland, Tyrol, and other European mountain regions, this may be partly due to differences of climate and geologic conditions. The presumption, however, is that the frequency and effects of such slides will be duly recorded in our mountain regions with the increase of settlements and decrease of forest cover. As a proper protection against snowslides is even now called for, a chapter on their formation and prevention has been appended to this report.—B. E. F.

LOSS OF FOLIAGE.

In the early part of the year 1885 extensive belts of conifers along the Pike's Peak and Front ranges, in Colorado, suffered a loss of blighting of foliage, which many supposed would result in the death of the trees.

Inquiry developed the fact that such occurrences, though rare in this region, were not without precedent, and were probably caused by sudden and extreme atmospheric changes. The trees so affected usually regain their foliage, although it is believed their vitality is impaired.

RELATIONS OF FOREST PRESERVATION TO AGRICULTURE.

In all countries the relations between forests and agriculture are more or less intimate. The forests receive moisture from the atmosphere, store it in their recesses, and through springs and running streams send it forth to water the land. Forests in proper proportion meliorate the severities of climate, rendering a country habitable for man and adapted to the growth of fruits and grains suited to his needs. Floods and droughts seldom occur in a region of forests. Forest products enter into all human activities, and it may be said that the race could not exist in the absence of forests.

In the Rocky Mountain region, where arid or semi-arid conditions prevail, the most important office performed by the forests is the conservation and distribution of moisture. The countries at the base of the mountains, and surrounding them, would be uninhabitable were it not for the forests which partially clothe the latter. Were the mountains wholly stripped of that covering which nature has so wisely bestowed upon them, but little moisture would be gathered from the atmosphere, violent storms would often occur, and torrents and seasons of drought would take the place of existing conditions.

In this region the direct dependence of agriculture upon the forests is more plainly seen than elsewhere. Except in a few localities, field crops, orchards, and gardens are cultivated with the aid of irrigation systems, the water for which is taken from the mountain streams. Should the forests be destroyed, the streams, irrigation systems, and crops would meet a similar fate.

The relation existing between the Colorado mountain system with its forests, and the water supplies for agricultural purposes, is strongly stated by Prof. Cyrus Thomas, of the Hayden Survey, as follows:

> This eastern mountain group appears to have two culminating points or radiating centers; the northern, and principal one, lies immediately around the North and Middle Parks, and forms the rim of these elevated basins; the other lies immediately southwest of South Park. In the first of these, Blue River, White River, Yampah River, and North Platte take their rise. In the other, Grand River, the Rio Grande, Arkansas, and main branch of the South Platte have their sources. The parks act as huge cisterns for the reception of the numerous little mountain rivulets that flow down from the surrounding rim, collecting them together and discharging them at one outlet. Thus, the North Park collects the various streams which form the North Platte; the Middle Park those that form Blue River; South Park those that form the South Platte; the San Luis Park those that form the Rio Grande; and the upper Arkansas Valley, which is a true park, those which form the Arkansas River. Here, then, we see that five of the great rivers of this vast central region have their sources close together in this mountain area. Upon the peaks, ranges, parks, and forests embraced between the one hundred and fifth and one hundred and seventh meridians and the thirty-eighth and forty-first parallels, an area not exceeding 18,000 square miles, depend, in a great measure, the agricultural resources of an area of more than 100,000 square miles.

IRRIGATION SYSTEMS.

It may be safely predicted that, within a comparatively few years, the Rocky Mountain region and adjacent portions of the Pacific slope will have irrigation systems equal to any the world has ever known. The discovery that vast areas of land, once deemed sterile and worthless, are reclaimable by the application of water has given wonderful impetus to irrigation projects. Favorable legislation has been obtained, and various plans to effect the desired object have been well advanced.

By legislative act, in 1881, the State of Colorado created the office of State hydraulic engineer, and adopted a carefully devised code of irrigation laws. Since then numerous irrigation enterprises have been begun and successfully prosecuted in that State. In many cases incorporated companies have been formed for the construction of canals and reservoirs, and the distribution of water over wide tracts of land. In numberless other instances, individuals, under the rule of priority of use, have made smaller canals and ditches, appropriating water in accordance with their needs and the existing rights of others.

In the adjoining Territories, especially in Utah, systems more or less perfect have been introduced, and will be enlarged and improved as the necessities of the people may require.

The data that have been collected with regard to the location and extent of the irrigating canals and ditches of this region, changes in the volume and flow of streams, etc., are given in the tables and maps accompanying this report and in the descriptions of the several political divisions.*

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* See note on irrigation, page 61.

FOREST POLICY.

In the State of Colorado, and in the Territories of New Mexico, Montana, Idaho, and Utah, there are in round numbers 90,000 square miles of forest land. It is estimated that four-fifths of it still belongs to the public domain, equal to not less than 45,000,000 acres. To speak of a management of this domain would convey the erroneous idea that there exists such a thing as forest management in these mountains. While private owners may, perhaps, be somewhat careful in the cutting of their timber, and possibly may take measures to protect it against spoliation or fire, nothing of the kind can be said of the people's property.

Under existing laws and regulations with respect to this vast body of woodlands, it would appear that forest fires have almost undisputed sway; railway corporations freely use and waste the public timber; unscrupulous lumbermen fell more trees than they can use; while poor men, struggling to establish homes, often find it difficult legally to obtain timber enough for their personal use. The few special agents of the General Land Office, scattered through this wide region, from lack of numbers and proper system, are powerless to avert forest destruction. Alleged trespassers are often prosecuted, but rarely convicted. No forests are saved from fire, and few, if any, from the ax. The policy of withholding from survey the public timber lands in certain of the Territories is worthy of commendation, and is likely to prevent, for the time being, the entry or sale of such lands, but not the spoliation of the timber on the same.

That the present condition of affairs is, and has been for some time, noxious and detrimental to the best interests, present and future, of this region, has been recognized by every honest settler along the mountain range. While all are agreed that the existing policy is injurious, undesirable, and should be changed, the proposed remedies differ, often very widely.

The present administration of the Land Office has exerted itself to the utmost, with absolutely inadequate means, to guard the people's property, and the reports of the Commissioner in the strongest language make clear the necessity, and at the same time the impossibility, of protecting from depredation this part of the domain. The impossibility of dealing adequately under the present system often necessitates dealing unfairly, or seemingly so.*

The following extracts from letters received from representative men, in reply to inquiries as to the character of the present laws for the disposal of the public lands and the necessity for their amendment, will be of interest:

> The laws are not sufficiently strict to prevent denudation of the forest lands, fraudulent appropriation of timber supplies, and leaving of rubbish to cause forest fires.
>
> There is too liberal construction of the law allowing the cutting of timber for domestic purposes; under it many abuses are perpetrated.

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* See summary on page —.

It is difficult in a thinly-settled country to get proof that will convict of setting forest fires.

In discussing the question of forest management, European examples are not always valuable to us; the conditions are very different and our difficulties are greater.

The Government should take care of the forests on forest principles.

In portions of the mountain region every alternate section should be reserved for forestry purposes, including the planting of forest trees.

All timber lands at the heads of streams capable of furnishing sufficient water for irrigation should be withdrawn from market, and religiously preserved, protected and, when necessary, replanted.

One-half of the public forest lands should be sold to settlers, and the other portions placed under the care of experienced foresters and held by the Government forever.

Local forest officers should be appointed, with power to quell fires, make arrests, etc.

All timber lands should be sold, or else donated to the State, to be disposed of or protected under the State laws.

In the arid regions timber lands should be donated to the respective States.

The entire control of the forest growth (not the land) should be conferred upon the State. The State, being more directly interested in the subject-matter, would be better able to adopt such measures as would conserve its forest resources.

There should be State reserves, with foresters who live in the forests and guard them from fires and depredation. The timber should be disposed of under regulation, and for the use only of the people of the State, regard being had always for the preservation of the forest, so that it be not denuded.

Timber on public lands should be free to settlers, and no restrictions placed upon lumbermen who cut timber only for home consumption.

Settlers upon the public domain should be allowed to use timber from the public lands for their homes and farms before and after perfecting their titles under the homestead or pre-emption laws, regardless of the fact that the timber land may be designated as "mineral" or "non-mineral." This distinction is generally imaginary and fictitious and has no value in point of fact.

Land should be granted to actual settlers only under the homestead law. All other laws for the settling or disposal of the public domain, including the act relating to placer-mining claims, should be repealed.

Every settler upon the public domain, when he shall have perfected his title to a pre-emption or homestead entry, should be allowed to enter at Government price not more than 40 acres of timber land in the same district, provided his pre-emption or homestead entry shall not have a natural growth of timber upon it sufficient for its necessities.

Repeal the pre-emption law, and make it a misdemeanor for a homesteader to sell timber, or suffer it to be cut, more than is absolutely necessary for domestic purposes.

A system of leasing the public timber lands within clearly-defined boundaries, with specific rights and liabilities, under penalties, guarantied by bonds of forfeiture in case of non-compliance with the terms of lease, will prove the most efficient means of promoting the interests of American citizens seeking homes in the Rocky Mountain region.

Persons cutting Government timber should be required to obtain a permit from the local land office, with safeguards and restrictions to prevent waste or trespass.

It would be better to allow charcoal-burners and the cutters of mine timbers to take living timber from the public domain under proper restrictions, than to encourage the destruction of the forests by fire, in order that they may cut the deadened timber as they please.

Railroads should be required to use dead timber if possible; no question of mere convenience should be considered. Some method of chemical preservation should be required where ties and bridge timbers are obtained from the public lands.

The timber-culture act is inoperative, and offers facilities for fraud.

The good results of the timber-culture law overbalance all objections to it. An inspection of each claim before a patent issues would insure compliance with the law and prevent fraud.

The following extracts give valuable hints on one side of the question:

[Extract from a recent report (1886) of Hon. S. T. Houser, governor of Montana Territory, to the Secretary of the Interior.]

There seems, at least in one branch of Congress, a purpose to set aside a large portion of the forest-clad sections of our Territory for permanent forest reservations, with a view to protect the fountain heads of the great continental rivers. Under proper regulations and provisions for needed care such reservations might be of great use and value. But it must be remembered that there is no timber in this region save that which grows in the mountains where these rivers rise. If this country is to be occupied and developed, these forests will, to some extent, have to be put under tribute for various domestic and mining purposes and uses. It must be further remembered that this entire region is metalliferous, and it would not be wise to exclude from these forest reservations all explorations for mines.

Owing, no doubt, to a want of knowledge of our peculiar situation and the purposes of the laws of Congress, adopted in 1878, in reference to the cutting of timber on mineral lands in the Rocky Mountain States and Territories, there have been many seizures for violation of law during the past summer, and many instructions and interpretations and applications of the law that have generally been regarded by our people as unwarranted and fatal to their interests. Under the regulations since prescribed by your Department it is believed that all conflict and irritation will disappear, unless too restrictive an interpretation or construction is attached to the words of the law confining its operations to mineral lands.

[Extract from the report, for the year 1886, of Hon. E. A. Stevenson, governor of Idaho Territory, to the Secretary of the Interior.]

The thanks of the people of Idaho Territory are due to the Department of the Interior for the modification of rules 2 and 3 concerning the felling of timber, as secured by the circular of August 5, 1886. The modification was well-timed and is gratefully received; but there are still some regulations in force in the Department that work great injury in the Territories of the Far West. Idaho is blessed with limitless forests of timber, which are of incalculable value in this western country—a great portion of whose area consists of barren and treeless plains. To enable settlers to cultivate and redeem these desert plains lumber must be readily accessible, else their efforts to build homes would be unsuccessful. Many of the settlers are poor, having expended their all in securing their land and in improvements. Under the rules and regulations of the Interior Department the purchaser must enter into a certain written agreement with the lumberman, and must, further, file with the mill-owner a certificate, under oath, that he purchases such lumber exclusively for his own use. This formality must be gone through with every time a settler desires a little lumber. It is a great inconvenience. Then, again, it is a matter of expense, for the oath must be taken before some magistrate qualified to administer oaths, and fees must be paid therefor. To the poor settler this extra expense is a matter of some consequence. Such magistrates are not often, in this new country, in close proximity to the saw-mills. The natural obstacles encountered by settlers on this desert land are severe enough without additional ones being put upon them by the Government. It is a source of great benefit to our country that this land be settled up, and to this end the policy of the Government should be to remove obstacles from the path of the honest settler, not seek to retard his efforts by impracticable regulations. There are in this Territory great forests, sufficient to supply the home consumption without any apparent effect on their extent.

From personal observation it is safe to say that the entire local consumption of timber in this Territory does not equal the growth of the forests. Let the Government afford sufficient protection against forest fires, which, through carelessness, annually consume immense quantities of timber, and protect our forests against the inroads of scavengers and consumers from other States and Territories, and no fear need be entertained as to the preservation of the timber.

In conclusion, I may be permitted to say that in my opinion a general policy with respect to the public timber lands should embrace the following features:

(1) The withdrawal from sale, entry, or disposal under existing laws of all such lands.

(2) The creation by law of a forest commission, to be composed of three competent persons, and to hold office for a period of five years. This commission should be authorized and required (*a*) to adopt tentative measures for the protection and preservation of the public forests; (*b*) to examine and classify the public timber lands and determine what portions should be held permanently as forest reserves, and what portions, if any, should be disposed of; (*c*) to devise and submit for the action of Congress a proper system of forest management and extension, and a plan for the establishment and endowment of a national school of forestry. Congress to make due provision for the necessary expenses of the commission.

(3) The enactment of laws for the protection of forests and the planting and cultivation of forest trees should be encouraged in the several Territories.

(4) When any Territory shall become a State and shall have instituted good and sufficient forest laws, there should be conveyed to such State, in trust, the public forest lands within its borders, for the perpetuation of the forests thereon.

III.—FOREST CONDITIONS OF THE SEVERAL POLITICAL DIVISIONS.

NOTE.—For the purpose of obtaining information with respect to the forest conditions of the several parts of the Rocky Mountain region, circular letters of inquiry, embracing the following questions, were sent to persons in each county:

(1) What is the extent of forest land in your county, giving approximate number of square miles?

(2) What proportion of it is fully stocked, good for timber? What part of it is made waste by burning over? What part of it brush, of promising growth?

(3) What is the proportion of forest to other lands?

(4) What is the character of the forest growth now remaining, in the size and kinds of trees?

(5) What species of trees predominate?

(6) Name, in the order of their importance, the principal uses to which each kind of timber is applied?

(7) What special dangers threaten the forests in your county, as lumbering, consumption by railroads, fires, etc.?

(8) What are the chances for renewal, after the forests have been destroyed?

(9) Of what species of trees is the second growth usually?

(10) What kinds, if any, follow after the timber has been destroyed by fire?

(11) Is any planting done and to what extent, and with or without irrigation?

(12) Have you noticed any changes in the volume of water in the streams, as the trees in their vicinity have been cut off or burned? Is there less water in the streams than formerly? Have floods and droughts become more frequent? Is the flow of water in the streams more intermittent?

(13) Are any observations on rain-fall kept in your locality? If so, by whom, giving name and post-office address.

(14) Have any avalanches occurred in your section? If so, please give the particulars, when, where, and what, if any, loss of life and property.

(15) What measures would you suggest for the more adequate protection of forest growth?

(16) Give any other information upon the same general subject which may occur to you. So far as possible give definite and particular answers to the foregoing questions and known facts rather than general statements. If there is insufficient space on this sheet for your answers supplementary sheets may be used, care being taken to refer to the numbers on this sheet so as to prevent uncertainty or confusion.

Responses to the above were in many instance so long delayed and often so incomplete that a laborious and protracted correspondence became necessary. Although but few correspondents could identify and name, according to their botanical relations, the several species comprising the forests of their locality, nearly all could give common names, location, uses, and other descriptive matter.

To obtain further details concerning the forests of the region and their relation to agriculture and systems of irrigation, letters of inquiry, embracing the subjoined questions and a plat of the particular county, were sent to county surveyors and other civil engineers:

(1) Please give a brief and general topographical description of your county?

(2) What is the approximate total number of acres of land in your county suitable for agricultural purposes requiring irrigation?

(3) Is there a sufficient water supply to irrigate that amount? If not, what proportionate amount short?

(4) What is the approximate number of acres already under ditch?

(5) What is the approximate number of acres already irrigated?

(6) In your county what is the approximate total length of (*a*) irrigating ditches—main, secondary, small; (*b*) mining and milling ditches; (*c*) city water-works (and capacity in gallons), together with total capacity of each, in statutory inches or cubic feet per second?

(7) Has the volume of water in the streams of your county increased or diminished, to your knowledge? Is the flow of water in such streams any more or less intermittent than was formerly the case? If you have noticed any such changes, please state the causes, so far as known to you.

(8) What effect, if any, in your opinion, do the forests have on the water supply?

(9) What, in a general way, is the extent, character, and location of timber in your county?

(10) Please send sketch, noting (to the best of your knowledge) the situation of the timber, irrigating and other canals, and city water-works in your county; giving the timber in green and canals and water-works in blue. To assist you in answering this question, a miniature map of your county is inclosed herewith.

(11) What are the principal causes of the destruction of forests in your county, and what measures would you suggest for their more adequate protection?

(12) Please give any other suggestions upon the same general subject which may occur to you. If there is insufficient space on this sheet for your answers, supplementary sheets may be used, care being taken to refer to the numbers on this sheet so as to prevent uncertainty or confusion.

Answers to a portion of the above questions were quite generally returned. The estimates of forest areas, acreage of lands suitable for irrigation, etc., were, of necessity, approximate rather than exact.

IDAHO.

Idaho Territory is situated in the northwestern portion of the United States, and near enough to the Pacific to share in the climatic influence of the warm ocean currents which sweep northward along the western shores of the continent.

The Territory has an area of 86,400 square miles. It is a vast wedge-shaped plateau, traversed by numerous streams, which find outlet at the northwest through the channel of the Columbia. High and rugged mountains cover large areas in the northern and eastern parts; innumerable ranges span the interior, while in the west and south-central portions are broad table-lands and arable valleys. The Bitter Root and Cœur d'Alene are the most rugged and precipitous of the mountain ranges. Their summits are snow-clad throughout the year, as are also those of the three Tetons, noted peaks in southeastern Idaho. The highest elevations in the Territory range from 9,000 to 13,000 feet. The lowest point is at Lewiston, where the Snake and Clearwater Rivers unite at an elevation of 680 feet.

The published maps fail to convey an idea of the almost numberless ranges of this region. In a distance of 300 to 500 miles, from east to west, it is said "there is a range of mountains, on an average, every 10 to 20 miles. Sometimes the distance across the range in a straight line, from the bed of a stream in one valley to the bed of the stream in the valley beyond the range, is not more than 5 to 8 miles, while it is seldom more than 20 miles."

The many streams of the Territory, fed by perpetual snows, are of good volume. Their flow is quite regular and constant, reaching its maximum at midsummer, and shrinking to its minimum in midwinter. The principal river is the Snake. It rises in the mountains of northwestern Wyoming, flows through southern Idaho, and thence northward along the western border of the Territory to its junction with the Columbia. The Snake is a magnificent river, of nearly 1,000 miles in length; the greater part of the drainage system of the Territory is tributary to it. Other important rivers are the Salmon and Clearwater, affluents of the Snake.

From a comparatively small portion of southeastern Idado the drainage flows into the basin of the Great Salt Lake.

The northern part of the Territory is mainly a region of mountains and forests, with small prairies and narrow valleys available for agriculture. Here also are situated lakes Pend d'Oreille, Cœur d'Alene, and Kaniska, which vary in length from 20 to 60 miles, and are wide and deep in proportion.

Other well known lakes of the territory are the Cocolalla, Payette, and Bear. In southern Idaho are lava fields covering probably 1,000 square miles, extending east and west nearly across the Territory, and southward to Snake River. To the southwestward of these are extensive sage-brush plains, reaching to the mountains of Northern Nevada. It is estimated that within the Territory there are 6,000 square miles of "mountain, desert, and volcanic formation, entirely unfit for any use except that designed by nature, being utterly destitute of mineral, timber, or vegetation."

The climate of the Territory, modified and softened by warm winds from the western coast and by the prevalent sunshine, is mild and delightful, notwithstanding the northern latitude.

Though arid conditions prevail to a degree that often render agricultural operations dependent upon irrigation, there is in the mountain region sufficient moisture to secure a vigorous forest growth.

The finest timber in the Territory is found in the central portion, on the Payette River and its tributaries. In the swamps, at the junction of Lolo Fork and Clearwater River, in Shoshone and Nez Perces Counties, is found Cedar timber (probably *Thuya gigantea*), the largest trees of which are 300 feet high, with trunks 6 to 9 feet in diameter. The wood makes handsome and valuable finishing lumber.

Yellow or Bull Pine is the principal timber tree. It grows on the lower mountains. The Black Pine or Tamarack is of small size and is found at elevations of 7,000 to 10,000 feet.

The Red or Yellow Fir grows on both the low and high mountains; the heart of the wood is quite red in color. The Mountain Mahogany is common in the Owyhee Mountains (southwestern Idaho). It is a small tree, rarely exceeding 20 feet in height, of irregular growth; has a hard, brittle wood and handsome grain. It is a favorite wood for canes and is much used for fuel.

Pine and Fir are largely used in the manufacture of charcoal.

There are saw-mills at Lewiston, Coeur d'Alene Lake, Spokane, and other points in the Territory. It is estimated that the amount of lumber manufactured during the year 1886 was 50,000,000 square feet, and that an equal amount of timber was used for fencing and fuel. Much of the lumber was exported. The importations of lumber, estimated at 9,000,000 square feet during the year 1886, were mostly cross-ties and timber for railway uses, which consisted mainly of Fir from Oregon and Washington.

The bulk of the shingles used are of native Pine. Some Redwood shingles are brought from the west, but iron and other kinds of prepared roofing are largely supplanting wooden shingles.

Territorial laws have recently been enacted imposing penalties for the willful or careless setting of forest fires, or failure to extinguish camp fires, etc. Also by legal enactment an annual "Arbor Day" has been designated for the planting of trees throughout the Territory.

Except in a small portion of the Territory north of Salmon River, irrigation is necessary in the cultivation of crops. The conservation of the mountain streams is of great importance. Millions of acres of land suitable for agricultural purposes can be made productive only by systems of irrigation, and these should be encouraged and promoted by a liberal policy on the part of the Government.

The people of the Territory earnestly desire the continuance of the desert land act, under which vast tracts of arid land may be reclaimed and made valuable. In many of the counties irrigation companies have been organized and large canals and auxiliary ditches constructed.

ADA COUNTY.

Total area, 3,500 square miles; estimated forest area, 50 square miles.

This county, in which is Boisé City, the Territorial capital, is situated near the southwest corner of the Territory. Snake River forms its boundary line at the southwest. The Boisé River divides the county into two nearly equal parts. The southern portion consists of rolling lands, too high for irrigation. The northern part is divided by the Payette River, and has many narrow and fertile valleys.

The only timber in the county is a narrow belt of Pine and Fir on the mountains of its eastern border, and a growth of Cotton-wood and Willow along the Boisé River.

ALTURAS COUNTY.

(Total area, 16,700 square miles; estimated forest area, 2,500 square miles.)

This county is bounded on the south by the Snake River, and is drained by its tributaries. The northern portion is mountainous, while the valley of the Snake is rolling and consists of sage-brush plains and almost impassable lava beds. The bulk of the timber is found in the northwest part of the county, and consists of Yellow and Black Pine, Fir, and Spruce. Red Fir and Black Pine are the predominant species. They do not grow large, nor are they very abundant. Aspen is found in the mountains, and Cottonwood along the streams.

A little planting is done, with the aid of irrigation.

BEAR LAKE COUNTY.

(Total area, 1,200 square miles; estimated forest area, 40 square miles.)

This county is situated in the southeast corner of the Territory, and is divided into two unequal portions by the Bear River and Bear Lake. Streams tributary to the river and lake rise in the mountain ranges which traverse the eastern and western portions of the county.

About one-half the area of the county is agricultural land. The remainder is broken and mountainous and composed of timber or grazing lands.

The average altitude is 5,900 feet. The rain-fall is chiefly in spring and autumn. Crops are cultivated mainly by means of irrigation.

The timber is mostly situated along the ravines near the crest of the high range which forms the western border of the county.

There is also some scattering timber on the slopes of the range in the eastern part. About one-third of the timber is fully stocked, one-third brush, and the remainder burned over.

The forest growth consists of White and Yellow Pine, White Fir, Mountain Mahogany, White Cedar, Cottonwood, and Aspen. Pine and Fir predominate.

Very little tree planting is done except on a few timber-culture claims, with the aid of irrigation. Small fruits are grown to some extent, and also some of the hardier large fruits.

BINGHAM COUNTY.

(Total area, 13,600 square miles; estimated forest area, 150 square miles.)

This county is also in the southeastern part of the Territory. It is well watered, the Snake and Bear being the most important rivers. The surface is greatly varied, and includes mountains, table lands, sage plains, valleys, and swamps. There is a large proportion of agricultural and grazing lands.

The little timber there is in the county is situated mainly in the northeastern part, and in canyons and narrow valleys. It is estimated that one-half is well grown, and the larger portion of the remainder is thrifty young Fir (red) and Cottonwood. No forest fires have occurred for a number of years. On a few timber-culture claims trees are grown with the aid of irrigation.

BOISÉ COUNTY.

(Total area, 2,500 square miles; estimated forest area, 1,100 square miles.)

Boisé county is situated in the central southwestern portion of the Territory. It has a rolling surface, and is watered by tributaries of the Payette and Boisé Rivers. Long Valley, about 75 by 15 miles in extent, and Garden Valley, also of large size, contain rich farming lands. There are wide tracts of grazing land in different parts of the county.

Some of the finest timber in the Territory grows here, covering from one-half to two-thirds of the area of the county. The predominant species are Yellow and Black Pine, Red Fir, and Balsam.

CASSIA COUNTY.

(Total area, 4,300 square miles; estimated forest area, 100 square miles.)

This county occupies a central position upon the southern border of the Territory. Snake River bounds it on the north, and it is watered by tributaries of the same stream. The surface of the county gradually rises from the Snake River south to the Utah line, where it becomes rough and mountainous, but interspersed with numerous valleys of greater or less extent. It is essentially a stock-growing county, and as such ranks among the first in the Territory.

The winter climate is cold and changeable. The amount of snow-fall in the valleys is not very heavy, but immense quantities accumulate in the mountains, which afford vast stores of moisture for the growing crops when the hot days of summer come. There is a great deal of rain in the valleys during the winter season, or from about the 1st of November to the middle of April. During the remainder of the year rain seldom falls, except occasionally a shower about the 1st of July. Consequently no crops can ordinarily be raised without irrigation.

The forest area is very limited and confined almost wholly to the mountains of the southern portion. Yellow and Black Pine and Balsam Fir are the principal timber trees. Good sawing timber, however, is getting scarce, although there is plenty of an inferior quality to furnish the county with rough lumber for a long time to come. The supply for fuel is inexhaustible. Cedar grows abundantly on the low mountains, and there are large bodies of Pine of small growth farther up on the mountains and in the canyons. There is some Mountain Mahogany and Nut or Piñon Pine, both of which make superior fuel.

CUSTER COUNTY.

(Total area, 5,800 square miles; estimated forest area, 1,900 square miles.

This county is centrally located in the Territory. It is broken by many low mountain ranges. The Salmon River, pursuing a zigzag course in a northeasterly direction through the county, receives the waters of eleven large affluents. Lost River and its tributaries water the southeastern part of the county. The topography of the region is greatly varied, and agricultural, grazing, and timber lands cover nearly the entire area. In the western part of the county are a number of small lakes.

Nearly one-half of the county is forest land. Very little, if any, has been made waste by burning. Pine, Fir, and Cottonwood are the predominant trees. The timber is inferior, the trees rarely exceeding two feet in diameter of trunk. Cottonwood is used mostly for fuel.

With the exception of a few fruit trees no tree planting is reported.

IDAHO COUNTY.

(Total area, 9,200 square miles; estimated forest area, 1,950 square miles.)

Idaho County is essentially a mountainous region, the principal portion of the Salmon River Mountains being included within its boundaries. These mountains are in no well-defined range, but are a vast collection of irregularly scattered peaks, overtopping a wilderness of lesser peaks, all of a rugged and forbidding aspect. The average altitude is about 6,000 feet, though many peaks have an elevation of nearly double that height.

The county is watered principally by the Salmon River and its tributaries. The northern portion is drained by some of the forks of the Clearwater. Salmon River cuts a deep chasm through the county from east to west. Its valley is from 3,000 to 4,000 feet lower than the average altitude of the mining camps scattered through the adjacent mountains, causing a marked difference in climate. In the winter snow rarely falls before February, and frequently the ground is not whitened during the year, while in the surrounding mining camps the snow covers the mountain sides from 4 to 8 feet in depth.

Camas Prairie, comprising an area of six to ten townships on the western border, is the only agricultural portion of the county.

The forests cover the outer portions of the county. Three-fourths of the timber-lands are well stocked, one-eighth is young growth, and one-eighth made waste by recent fires. The principal species of trees are Cedar, White Pine, Tamarack, and Red and Yellow Fir. Some of the timber is very large and fine, growing from 1 to 6 feet in diameter. In the open country considerable tree-planting is done without the aid of irrigation.

KOOTENAI COUNTY.

(Total area, 4,830 square miles; estimated forest area, 2,400 square miles.)

This county is in the extreme northern or "pan-handle" portion of Idaho. The high and rugged Cœur d'Alene Mountains extend through the central part from east to west. Flanking this range are lakes Pend d'Oreille, Kaniska, Cœur d'Alene, and others of lesser note. Clark's Fork of the Columbia and the Spokane are the principal rivers.

The forest growth, which is pretty well distributed over the county, consists mainly of Yellow and Black Pine, Fir, Cedar, Cottonwood, Yew, Alder, and Willow; Pine predominating. A small portion has been burned over and made waste. The finest timber of the territory is found in this county on the waters of the Cœur d'Alene, St. Joseph, and St. Mary's Rivers. One authority states that on the banks of the first named thousands of immense trees can be seen, the trunks of which will measure from 1 to 13 feet in diameter. This has long been known as the best timbered section of Northern Idaho, and is second only in importance to that on Puget Sound.

On the banks of Kootenai Lake there is a large body of fine saw-timber. For miles on either side of Pack River there are bodies of good timber along its course.

The line of the Union Pacific Railroad passes directly through this region, and a heavy draft is likely to be made upon its timber resources.

A little tree-planting is done in Kootenai County on timber-culture claims without the aid of irrigation.

LEMHI COUNTY.

(Total area, 3,870 square miles; estimated forest area, 2,100 square miles.)

This county has for its northeastern boundary a portion of the main Rocky Mountain range. It is watered by the Salmon River, its main affluent, the Lemhi, and numerous smaller streams tributary to the two named. Two great valleys, the Lemhi and Pahsamari, and a few lesser ones, afford some 300,000 acres of land suitable for cultivation.

The heaviest timber is found along the north fork of Salmon River, and within 35 miles of Salmon City. Pine trees with trunks 3 and 4 feet in diameter, and attaining a height of 60 and 70 feet, are common. Timber also extends along the mountains on either side of the valleys occupying the central portion of the county. White and Black Pine and Fir are the predominant forest trees.

NEZ PERCES COUNTY.

(Total area, 3,100 square miles; estimated forest area, 450 square miles.)

The Salmon River, extending through the county from east to west, divides it nearly equally.

The average elevation is about 3,000 feet; the lowest altitude in the Territory (680 feet above sea level) is at Lewiston, in this county. The climate is mild, and the rain-fall sufficient for the growth of crops. Agriculture and stock-raising are the chief industries.

The timber, which is mostly situated in the mountains along the eastern border of the county, consists of Yellow and Black Pine, Red and

White Fir, Cedar, and Larch. Much of the timber is large, reaching a diameter of 3 to 5 feet.

A few forest trees are cultivated on timber-culture claims without the aid of irrigation.

ONEIDA COUNTY.

(Total area, 2,500 square miles; estimated forest area, 150 square miles.)

This county is situated in the southeast corner of the Territory and is an agricultural region. There is but little timber, and that is found in the central and southeastern portions.

Red Fir, Cedar, and Aspen are the predominant forest trees.

OWYHEE COUNTY.

(Total area, 7,430 square miles; estimated forest area, 300 square miles.)

This large county occupies the southwestern corner of the Territory. Snake River forms its northern boundary. In the eastern part are extensive sage-brush plains. As a whole the county is mainly adapted to stock-raising.

The only timber reported is a body covering the South Mountain range, in the west central part.

SHOSHONE COUNTY.

(Total area, 5,200 square miles; estimated forest area, 1,900 square miles.)

This county is situated in the northern part of the Territory. The Bitter Root and Cœur d'Alene Mountains, which form a part of the Rocky Mountain chain, constitute its northeastern boundary. Its principal streams are the Lolo Fork and North Fork of the Clearwater River.

The greater portion of the county is mountainous, and includes large bodies of timber. The forest growth consists of Red and White Fir, Yellow and White Pine, White Spruce, Hemlock, Tamarack, Cedar, Yew, and several minor species. The timber grows of medium size on the mountains, and larger on the bottom lands; portions of it on the high ridges have been destroyed by fire.

WASHINGTON COUNTY.

(Total area, 2,500 square miles; estimated forest area, 900 square miles.)

This county, situated in west central Idaho, is bounded on the west by Snake River. The Weiser River and other streams water the interior of the county.

Black and White Pine, Red and White Fir, Hemlock and Balsam, are the principal species of forest trees. Pine predominates. The heaviest bodies of timber are found in the northern and eastern parts of the county. The trees composing the forest vary greatly in size, the trunks measuring from 1 to 6 feet in diameter. There is not much brush, and but little timber has been destroyed by fire.

MONTANA.

The Territory of Montana, having the form of an immense parallelogram, and embracing a superficial area of 145,776 square miles, occupies a large space upon the map of the United States. It is situated in the extreme northern tier of Territories, bordering upon the British Possessions. The Rocky Mountain chain, constituting the Continental Divide, passes through the western portion. About four-fifths of the entire area belongs to the Atlantic slope, being drained by the Missouri River and its tributaries, and one-fifth to the Pacific slope, being drained by the headwaters of the Columbia. The mountain range separating so unequally the two parts of the Territory is comparatively low, and the contiguity of the region to the Pacific Ocean renders it, to a degree, subject to the climatic influences governing the western coast.

Three-fifths of Montana, comprising the eastern and central portions, is a rolling plateau, having an average elevation of 3,000 feet, broken by mountain spurs, buttes, and headlands, and watered by numerous streams. It is pre-eminently a grazing country, and is largely covered with the nutritious bunch grass. In this eastern part, north of the Missouri River, are vast plains. The western two-fifths of the Territory is mountainous.

As a general thing the mountains of this section are less rugged than in the Colorado group; although here and there are sharp angular peaks, yet as a general rule, instead of the rocky, jagged sides and serrated crests, there are smooth slopes and rounded outlines. The height of both mountains and valleys, as will be seen from the list of elevations presented below, is much less than that of the great mountain belt of Colorado and Wyoming, and even that of New Mexico, Utah, and Nevada.

Elevations in Montana, chiefly along a line running east and west near the middle of the Territory:

	Feet.
Fort Union, at the mouth of the Yellowstone	2,022
Trading Post, on Milk River	2,388
Fort Benton	2,780
Forks of Sun River	4,114
Lewis and Clark's Pass	6,519
Blackfoot Fork, near the mouth of Salmon Trout Creek	3,966
Blackfoot Fork, near its junction with Hell Gate River	3,247
Missoula River, near the mouth of St. Regis de Borgia	2,897
Summit of Cœur d'Aléne Mountains, at Cœur d'Aléne Pass	5,089
Fort Owen, in Bitter Root Valley	3,284
Deer Lodge City, in Deer Lodge Valley	4,768
Prickly Pear Valley, near Helena	4,000
Little Blackfoot, or Mullen's Pass	6,283

From this list we see that the western or intermontane basin has a depression less than 3,000 feet above the level of the sea; and that the least altitudes of the eastern slope range from 4,000 to 2,022 feet above the level of the sea. Comparing these with the altitudes of the other Territories, we find the difference much greater than would be anticipated. For this purpose I give here the elevations of a few points:

	Feet.
Albuquerque, N. Mex	5,032
Santa Fé, N. Mex	6,840
Denver, Colo	5,300
Green River, at the railroad crossing, Wyoming	6,140
Salt Lake City, Utah	4,350
The Humbolt Sink, Utah	4,017
Fort Laramie, Wyo	4,519
Sweet Water River, at Independence Rock, Wyo	5,998
South Pass City, Wyo	7,857

From this we see that even the lowest point of the Great Basin near the "Humboldt Sink" is 1,126 feet above the mouth of the St. Regis de Borgia, and 733 feet above Fort Owen. This very important fact in regard to the physical geography of this Territory will serve as an explanation of its comparatively mild climate, notwithstanding its northern latitude.

Probably none of the southern and central ranges reach the line of perpetual snow. Those in the extreme north are unexplored. It is said that glaciers flow from some of them.

The western or mountainous portion of Montana is interspersed with many fine valleys well adapted to agriculture and stock raising. The principal forests of the Territory are in this section.

The most dense and continuous bodies of timber are found on the western flanks of the main range, and on the Cabinet, Cœur d'Aléne, and Bitter Root Mountains, which are contiguous to it, or form the boundary line between Montana and Idaho. These forests, which extend to eastern and northern Idaho, are the most extensive and valuable of any in the Rocky Mountain region. They guard the sources of many important streams, and furnish timber supplies for an adjacent treeless territory of wide extent. Their careful conservation is of the greatest consequence.

The forests of Montana are composed mainly of Yellow Pine (*Pinus ponderosa*); White Pine (*Pinus flexilis*, *Pinus albicaulis* and *Pinus monticola*), Lodge-Pole or Tamarack Pine (*Pinus Murrayana*); Red or Yellow Fir (*Pseudotsuga Douglasii*); White or Balsam Fir (*Abies grandis*); Cedar (*Thuya gigantea* and *Juniperus Virginiana*); and Yew (*Taxus brevifolia*). The Yellow Pine and Red Fir predominate, forming the bulk of the forests at the lower altitudes. At higher elevations are found the White Spruce, Tamarack, and Balsam.

The deciduous species most worthy of mention are the Cottonwood (*Populus monilifera* and *P. angustifolia*); Balsam Poplar (*P. balsamifera*); Aspen (*P. tremuloides*); Box-Elder (*Negundo aceroides*); and Mountain Mahogany (*Cerco-carpus ledifolius*).

Yellow and White Pine, and White Spruce are the principal timber trees. The first named is the largest and most useful, and furnishes most of the building lumber, both common and finishing. In favorable situations the trees of this species attain a height of 100 feet and the trunks a diameter of 6 or 7 feet.

The White Pine is of smaller growth than the Yellow, the wood is softer and more subject to decay. The two kinds are, however, used for many similar purposes.

Lodge-pole Pine seems to be a stunted variety of *Pinus Murrayana.* It is a slender tree which covers large areas upon the mountains. It grows to a height varying from 20 to 100 feet, with trunks from 2 to 10 inches in diameter, often forming masses so nearly impenetrable that trails must be made with the ax. A section from the trunk of one of these trees measures 2½ inches in diameter and has fourteen layers of annual growth. A lumberman of experience states that good saw-timber can be had from the same kind of pine where the growth is less dense and crowded. The smallest kinds are extensively used for fencing, "logging" for mines, and by the Indians in the construction of their lodges. A similar growth is found in portions of Wyoming and Colorado.

Cottonwood and Box-Elder border the streams at comparatively low elevations. The Aspen covers large surfaces which have been denuded of the original forest growth. It prefers northern slopes and narrow moist valleys.

Although the forest area of the Territory is large, it is being rapidly reduced. The destruction by forest fires is almost beyond computation; railroads use and transport immense quantities of timber; lumbering operations cause a large and steady drain upon the forests; while the consumption of timber for mining purposes is of equal magnitude.

The Territorial laws prescribe penalties for the willful or careless setting of fires, or failure to extinguish them; and county commissioners are required to post notices annually in conspicuous places, calling attention to the provisions of the law. Notwithstanding these precautions, forest fires are frequent and destructive in the extreme.

A recent legislative act provides for rebatements in taxation to persons planting and cultivating forest trees, under certain conditions named in the law.

Irrigation is practicable at different points upon all streams near the mountains, and it is stated that by this means crops are cultivated in every county of the Territory.

East of Great Falls the Missouri River has cut a channel 600 to 900 feet deep, through the table-lands to the Dakota line. This gives to its tributaries a very swift current, although their channels are quite deeply sunken below the adjacent plains. In the Yellowstone system the waters flow somewhat nearer the general level.

A number of great irrigation enterprises have been undertaken. The canal of the Minnesota and Montana Land and Improvement Company, in Yellowstone County, is about 40 miles long by 35 feet wide, and 5 feet deep. Another large canal, in Choteau County, is 75 miles in length. Others of similar character are in process of construction. Irrigation systems are greatly needed for the reclamation, under the desert-land act, of sterile tracts. The repeal of that act, as proposed, might be a serious mistake.

The numerous valleys of the Territory are remarkably fertile, and, with proper facilities for irrigation, yield large returns in wheat, oats, barley, and all kinds of vegetables unsurpassed in quality.

BEAVER HEAD COUNTY.

(Total area, 2,800 square miles; estimated forest area, 1,100 square miles.)

This county is situated in the extreme southwestern corner of the Territory. It is bordered on the north, west, and south by the main Rocky Mountain range. Beaver Head and Big Hole Rivers are its principal streams. They flow through a long reach of country and find outlet at the northeast, through the Jefferson River, into the Missouri.

The surface of the county is much broken, and includes many detached ranges and spurs, which, in some instances, are comparatively high and rugged. There are a number of arable valleys, and quite an extent of rolling, open country suitable for grazing.

Upon all the mountains, except at the highest elevations, there is a forest growth, but usually not dense nor of great value for lumber. The forests, however, afford timber supplies for the ordinary local uses, and serve to protect the head-waters of the streams.

Red Fir, Black Pine, or Tamarack, White Pine, and White Spruce are the predominant species. Black Cottonwood (*Populus angustifolia*), which here grows large and tall, borders many of the streams.

Forest fires have destroyed much timber in the county, but as the winter snows are heavy and the climate not extremely arid, a new growth of the same species soon appears.

CHOTEAU COUNTY:

(Total area, 26,000 square miles; estimated forest area, 350 square miles.)

The greater part of this immense county, nearly all of which is in the plains region, is held as an Indian reservation. It is situated in the north-central part of the Territory, and is watered by the Missouri River, the Milk, Marias, and other tributary streams.

The small amount of timber the county contains is found upon the Sweet Grass Hills in the north, the Bear Paw and Little Rocky Mountains at the northeast, the Highwood Mountains in the southern portion, and on the foot-hills of the main range in the extreme western part.

The forests are composed almost wholly of an inferior growth of Red Fir and White Pine, not more than 5 or 10 per cent. of which is good saw-timber. A scanty growth of Cottonwood lines the streams.

It is stated that forest fires have not been frequent. When they do occur, the second growth is usually of the same species as the original.

CUSTER COUNTY.

(Total area, 20,000 square miles; estimated forest area, 200 square miles.)

Custer County, situated in the southeastern corner of the Territory, is another of the "plains counties." It is an agricultural and grazing region, and is watered by the Yellowstone, Powder, Tongue, and Rosebud Rivers and their affluents.

There is but little timber in the county, and that is found in the southwestern part.

DAWSON COUNTY.

(Total area, 2,700 square miles; estimated forest area, 200 square miles.)

This, one of the largest counties of the Territory, is situated in its northeastern corner. More than one-half of its area, at the north, is still held as an Indian reservation. It is wholly in the plains region. The Missouri River flows through the central part and the Yellowstone crosses the southeast corner. The only timber of any importance—and that very limited in extent—is situated in the piney buttes, in the southwestern portion of the county.

DEER LODGE COUNTY.

(Total area, 5,000 square miles; estimated forest area, 2,400 square miles.)

This county lies upon the western slope of the Continental Divide. The main Rocky Mountain range forms its northern, eastern, and, in part, its southern boundaries. The area of this county is quite equally divided between mountains and valleys, the most notable of the latter being Deer Lodge Valley, which is 30 miles long and from 3 to 10 miles wide.

Numerous streams afford a plentiful water supply for irrigation and other purposes.

All of the mountains are more or less timbered, the heaviest growth being found in the northern and southwestern parts of the county. Red Fir, White and Yellow Pine and Cedar, are the principal species of forest trees. Fir and "Lodge-pole Pine" (a variety of the White Pine) predominate.

One-half of the timber lands is covered with Lodge-pole Pine, one-fourth has trees of large growth, and one-fourth is brush and burned over. The trunks of the larger species attain a diameter of 4 to 5 feet.

FERGUS COUNTY.

(Total area, 7,500 square miles; estimated forest area, 700 square miles.)

This county is situated in the central part of the Territory. The Muscle Shell River, a tributary of the Missouri, bounds it on the south and east. Its average elevation is about 3,500 feet above sea-level. One-third of the area is mountainous, and covered with a scanty growth of timber. The remaining portion consists of long, narrow plateaus, with deep valleys and ravines at the sides. The bottom-lands, bordering the streams, are of small extent, and in some parts are too stony for cultivation. To a great extent the soil is gravelly. This, in connection with the broken configuration, and prevailing arid conditions, will greatly limit agricultural operations.

The timber lands are situated in the central and western portions of the county. The greater part are thinly wooded, the forest growth appearing on rocky ridges, buttes, and the sheltered sides of plateaus. The predominant species are Yellow and White Pine and Fir. Only the first two grow large enough for lumber. The White Pine is small, and is much used for fencing poles. A scattering growth of Cottonwood and Box-elder along the streams furnishes more or less fuel.

About one twenty-fifth of the timber area is fully stocked, and one-fiftieth is brush.

Forest fires have been very destructive. A correspondent, under date of August, 1886, describes one then prevailing on the Fort Maginnis military reservation. He recounts the unavailing efforts of citizens to subdue it, and the utter indifference with which the matter was viewed by the commandant of the post, who refused to extend any aid in the premises.

Tree-planting, either with or without the aid of irrigation, is deemed impracticable. The atmosphere contains so little moisture that trees sunburn in summer and freeze dry in winter.

GALLATIN COUNTY.

(Total area, 7,100 square miles; estimated forest area, 1,600 square miles.)

Situated upon the southern border of the Territory at a moderate elevation, and abundantly watered by streams flowing from Yellowstone Park, this county ranks among the first in Montana for fertility and productiveness. Its surface is greatly varied, and includes mountains, foot-hills, and valleys.

Most of the mountain slopes are covered with timber; the trees, however, do not grow large. Yellow and White Pine and Fir are the predominant species. Lodge-pole Pine is the most common variety, and occupies large areas. Cottonwood grows along the streams. About 40 per cent. of the timber land has been burned over.

JEFFERSON COUNTY.

(Total area, 2,200 square miles; estimated forest area, 350 square miles.)

This county lies upon the eastern slope of the main range and is centrally situated in the western or timbered portion of the Territory. The

Jefferson and Missouri Rivers, respectively, form its southern and eastern boundaries. It is well watered by numerous tributary creeks.

The timber, confined mostly to the mountain slopes, is neither very heavy nor dense. Yellow and White Pine and Spruce (variety not named) are the principal species of forest trees. Cottonwood borders the streams.

Complaint is made that lumbermen cut large quantities of timber which they fail to use, leaving it on the ground to decay.

With the aid of irrigation, a few forest trees are cultivated for ornamental purposes.

LEWIS AND CLARKE COUNTY.

(Total area, 2,100 square miles; estimated forest area, 400 square miles.)

This county lies directly north of Jefferson and, in common with the latter, is bounded on the west by the main Rocky Mountain range. The Missouri and Sun Rivers, respectively, constitute its eastern and northern boundaries.

One-half or more of the county is mountainous and more or less timbered. On the sheltered slopes of the mountains, the trees are tall and straight, varying in diameter of trunk from 4 inches to 2 feet. In situations where the southwest winds have unobstructed sweep, the forest growth is scanty and dwarfed. Yellow and White Pine and Red Fir are the predominant trees and constitute the principal timber. As in most other parts of this region, Cottonwood borders the streams.

Some claims have been taken under the timber-culture act, trees being cultivated with the aid of irrigation.

MADISON COUNTY.

(Total area, 4,500 square miles, estimated forest area, 900 square miles.)

Madison County is situated near the southwest corner of the Territory. Its area embraces mountains, valley and grazing land in almost equal proportions. The Jefferson and Madison are its principal rivers.

The forests, composed chiefly of Red Fir and White Pine, grow upon the mountain ranges, which have quite general distribution throughout the county. The Fir reaches a size of 10 to 40 inches in diameter of trunk, while the Pine is much smaller, rarely exceeding 12 inches in diameter. Cottonwood fringes the streams. About one-fourth of the forest growth is good timber, one-fourth young trees and brush, and the remainder made waste by burning.

It is said that forest fires occur every fall in the dry season.

Trees are grown to a limited extent, and with indifferent success, on timber-culture claims, with the aid of irrigation.

Some loss of life and property by avalanches is reported.

MEAGHER COUNTY.

(Total area, 5,700 square miles; estimated forest area, 1,100 square miles.)

This county is situated near the center of the Territory. The Missouri River forms its western boundary. Other important streams are the Muscle Shell and Smith Rivers. Mountains, valleys, and foot-hills, or grazing lands, further vary the surface of the county.

The forests are mostly situated on the mountain slopes, the main sources of timber supply being the Big and Little Belt, Snowy and Elk Mountains, and portions of the Highwood and Crazy ranges. The best timber is usually in the least accessible districts It is estimated that one-tenth of the forest area is good timber and three-tenths promising second growth. The remainder is brush and lands made waste by fire.

Yellow and White Pine and Spruce are the principal timber trees. Cottonwood is used to some extent for fuel.

The following list includes the names and location of the different species native to this county:

Yellow Pine (*Pinus ponderosa*), Smith River and elsewhere.
White Pine (*P. albicaulis*), Little Belt Mountains.
Lodge-pole Pine, wrongly called Tamarack (*P. Murrayana*), Little Belt Mountains.
Blue (or White) Spruce (*Picea pungens*), all mountain ranges.
Cottonwood (*Populus monilifera*), widely distributed.
Black Cottonwood (*P. angustifolia*), all large streams.
Balsam Poplar (*P. balsamifera*), Belt Creek.
Aspen (*P. tremuloides*), mountain ranges.
Box-elder (*Negundo aceroides*), margins of streams.
Dwarf Maple (*Acer glabrum*), Little Belt Mountains.
Mountain Mahogany (*Cercocarpus ledifolius*), Little Belt Mountains.
Wild Cherry (*Prunus demissa* and *P. Pennsylvanica*), creek valleys.
Black Birch (*Betula occidentalis*), borders of streams.

MISSOULA COUNTY.

(Total area, 24,500 square miles; estimated forest area, 16,200 square miles.)

This county, of such great extent, is situated in the northwest corner of the Territory, and upon the western slope of the continental divide.

The Cabinet, Cœur d'Alene, and Bitter Root Mountains and their outlying spurs occupy a large portion of the western half of the county, It is watered by the Kootenai, Clarke's Fork of the Columbia, Missoula. Bitter Root, Pend d'Oreille and other streams. Flathead Lake, a sheet of water 30 miles in length by 10 in width, is situated in the northeastern portion. A few other small lakes are found in the same region. The surface of the county is about one-third mountains and hills, and the remaining part consists of valleys and plateaus. Agriculture and fruit-raising are leading industries; many fine orchards have been grown.

The mountains are not rugged and are comparatively low, rarely exceeding 8,000 feet in altitude. They, as well as the foot-hills, are usually covered with timber. Some of the low, Rocky Mountain spurs at the eastward, however, are quite bare. About three-eighths of the forest growth is good timber; as much more is promising young growth, while the remainder has been made waste by fire.

The leading species of forest trees are Yellow and White Pine, Red and White Fir, White Spruce, Tamarack, Cedar (*Thuya gigantea*), Larch, and Balsam. In the bottoms and along the streams are found Balm of Gilead, Birch, Alder, Willow, etc. The Pines, Firs, and Tamarack furnish most of the lumber supplies. The Yellow Pine grows large, and is the predominant forest tree.

At higher elevations the White Spruce is the leading species.

SILVER BOW COUNTY.

(Total area, 576 square miles; estimated forest area, 60 square miles.)

The county of Silver Bow, situated upon the crest of the main Rocky Mountain range, is one of the principal mining centers of the region.

Mining interests have greatly flourished here, but the forests have suffered in a corresponding degree. The demand for mining timbers and wood for charcoal manufacture has been so great, that the once valuable forest lands of the county have been almost wholly stripped. There is but little, if any, chance for reproduction of the forest growth. A little timber still remains in the western part of the county, but is likely to be consumed during the next three years.

Yellow and White Pine, Red Fir, and White Spruce are the predominant species. The Fir grows to a size of 6 to 15 inches in diameter of trunk, and the Spruce reaches an average diameter of 15 inches. Lodgepole Pine grows from 2 to 6 inches in diameter. A small growth of Cottonwood and Willow is found along the streams. A correspondent writes:

> The timber question is a serious one for this part of the Territory. The consumption of timber is so great that the forests of western Montana will be cut off within the next ten years.

YELLOWSTONE COUNTY.

(Total area, 3,600 square miles; estimated forest area, 25 square miles.)

There are no mountains in this county, and no forests of importance. The Yellowstone River forms its southern boundary.

Upon the bottom lands and hills, skirting this river and its tributary creeks, is found a little timber, consisting of Pine, Cedar, and Cottonwood; none of which, unless the latter, attains large size. About one-eighth of the forest growth is said to be good timber.

CROW INDIAN RESERVATION.

(Total area, 7,200 square miles; estimated forest area, 700 square miles.)

This reservation is in the south-central part of Montana, bordering on the Territory of Wyoming. The Yellowstone River bounds it on the north; and the entire area is fairly well watered by the two Big Horn Rivers, the Nez Perce and Rosebud Rivers and their affluents, all of which are tributary to the Yellowstone.

In the southern part of the reservation are outlying spurs and foothills of the Wyoming ranges. These are covered to some extent with Pine, Fir, and Spruce timber. The foot-hills of the Snow Mountains, which encroach upon the western border of the reservation, also bear a forest growth, but no report concerning the same has been received.

WYOMING.

The Territory of Wyoming, in situation, exterior form, area, and configuration, has much in common with her southern neighbor, the State of Colorado. Both lie in the northern temperate zone, and cover portions of the great interior plateau where the open country and mountains meet. In both are high and rugged mountain ranges, wide plains, valleys, and powerful streams. One contains the distribution or radiating center of the water system of the Northwest; in the other is the distributive center of the water system of the Southwest.

The surface area of the Territory is 100,375 square miles and its mean altitude about 6,000 feet above the sea. The main Rocky Mountain range crosses it in a direction from northwest to southeast. This is flanked upon either side by minor ranges, groups, and spurs, the most prominent of which are the Big Horn Mountains in the north, the Laramie and Medicine Bow ranges in the south, and the Bear, Salt River, and Teton Mountains at the west.

In the southwestern part, and following the trend of the main range from northwest to southeast is an area of barren country, about 200 miles in length and from 50 to 90 in breadth. Its northern part comprises the "Colorado Desert," or Green River Basin; the central portion is mostly sage-brush and sand, and the southeastern part is known as the "Red Desert." The surface of this desolate region—which extends southward into western Colorado and eastern Utah—is broken by hills, sand dunes, and buttes.

As an offset to this, in the northwestern corner of the Territory is the Yellowstone National Park, a region remarkable for its grand and wonderful scenery. Here, amid snowy peaks and vast forests, are the sources of the Big Horn, Yellowstone, Madison, Green, and Snake Rivers; the first three finding outlet through the Missouri and Mississippi to the Gulf of Mexico, the next through the Colorado of the West to the Gulf of California, and the last through the Columbia to the Pacific Ocean. In this part of Wyoming are also a number of beautiful lakes, of which the Yellowstone is the best known.

The North Platte, Green, Big Horn, and Powder are the principal rivers. Numerous other streams, of greater or less importance, water the different portions of the Territory.

The climate, though cool and bracing, as befits a high altitude, is not rigorous except in the higher mountains. But slight falls of rain or snow occur during the year, so that the aggregate of sunny days is very great. The mean annual rain-fall, including snow, varies from 12 to 15 inches. The greatest humidity is from the middle of autumn to the middle of spring. Irrigation is depended upon for raising farm products, the rain-fall being insufficient to mature crops, except grass for grazing purposes.

Stock-raising is as yet the chief industry, though the natural resources of the Territory are extremely varied. It is estimated that one-eighth of its entire area is suitable for cultivation.

The forests of Wyoming are confined mainly to the mountain ranges. Some of them are of wide extent, and the timber quite dense and heavy; but, as a rule, they are not equal to those of the Territories farther north and west. The best timber is found on the southern part of the Big Horn Mountains, the central portion of the Laramie Range, Medicine Bow, and Sierra Madre Mountains, and the northern spurs of the Uintah Range, which extend from Utah into southern Wyoming. Upon nearly all of these mountains the snows are heavy, and remain, in part, throughout the year. The Shoshone, Teton, and Snake River ranges also bear quite heavy forests. The timber upon the eastern extension of the Sweetwater range and western portion of the Rattlesnake Mountains is light and scattering. The widest timbered area is in the northwestern part of the Territory, covering the Wind River, Shoshone, and other mountains of the main range, including the groups of Yellowstone Park.

There is considerable timber mostly Yellow Pine, upon the Black Hills near the Dakota line.

Measurements of the timber limits of various mountains have been made, which show the heights, in their respective latitudes, above which coniferous trees—the hardiest of any species—will not grow. The timber line of Mount Washburn is 9,900 feet above sea level, while the altitude of that mountain is 10,388 feet; the timber line of Mount Hayden, of the Teton range, is 11,000 feet, while its altitude is 13,858 feet above the sea; the timber line of the Wind River range is 10,160 feet, while its general altitude is 11,500 feet above the sea.

Yellow and White Pine and White Spruce are the principal timber trees. Many regard the Yellow Pine as the best and most useful tree, while others think the White Spruce furnishes the best timber for all purposes.

Lodge-pole Pine (*Pinus Murrayana*) is the prevailing forest tree in a wide area along the mountain range north and south of Laramie. It is also common in the northwestern and other portions of the Territory. It often replaces the original growth after fires, etc.

Red Cedar (*Juniperus Virginiana*) has a scattering growth upon the foot-hills and low elevations in many parts of the Territory.

The Cottonwood (*Populus monilifera* and *P. angustifolia*) fringes many of the streams.

The entire forest area of the Territory is estimated at 12,000 square miles. Large portions, however, are thinly stocked and other parts have been overrun by fire.

The several species, comprising, so far as known, the forest flora of the Territory, are named in the following list:

Yellow Pine (*Pinus ponderosa*, Dougl.).
White Pine (*Pinus flexilis*, James).
Black, or Lodge-pole Pine (*P. Murrayana*, Balfour).
Piñon, or Nut Pine (*Pinus edulis*, Engelm.).
White Spruce (*Picea Engelmanni*, Engelm.).
Blue (or White) Spruce (*Picea pungens*, Engelm.).
Black Spruce (*Picea nigra*, Link).
Red Fir (*Pseudotsuga Douglasii*, Carr).
Balsam (*Abies subalpina*, Engelm.).
Balsam Fir (*Abies balsamea*, Mill).
Red Cedar (*Juniperus Virginiana*, L.).
Cottonwood (*Populus Monilifera*, Ait.)
Cottonwood (*Populus angustifolia*, James)
Aspen (*Populus tremuloides*, Michx.).
Willow (*Salix longifolia*, Muhl.).
Green Ash (*Fraxinus viridis*, Michx.).
Box-Elder (*Negundo aceroides*, Moench).
Scrub Oak (*Quercus undulata*, Torr).
Mountain Mahogany *Cercocarpus ledifolius*, Nutt).
Mountain Mahogany (*Cercocarpus parvifolius*, Nutt).
Wild Plum (*Prunus Americana*, Marsh).
Wild Cherry (*Prunus Pennsylvanica*, L. f.).
Black Birch (*Betula occidentalis*, Hook).

A small tree, not included in the above, is known locally as "Iron Wood." It grows along the streams in bunches or clusters, the bark resembling that of the Red Cherry. It has long, slender stems, which are often used for fishing-rods. No complete description of this species has been obtained.

The principal demands upon the forest are for railway timbers and cross-ties, the manufacture of lumber—for local uses—and timber for fencing and fuel. But little if any timber is exported.

Common lumber, used in building, is mostly of the native wood. Laramie and Evanston are principal points of production of native lumber. Hard woods and Southern Pine for finishing and flooring are brought from the East; White Cedar shingles are obtained from the Pacific region. It is estimated that 40 per cent. of the lumber used in the Territory is imported.

The statutory laws prescribe a penalty of fine and imprisonment for the willful or careless firing of woods, marshes, or prairies, and satisfaction in damages to any person injured. Forest fires, nevertheless, are frequent and destructive.

No officers are specially charged with the enforcement of the forest laws, and although there may be violations of the same, the guilty parties are rarely if ever apprehended.

Wyoming is within the "arid belt," and irrigation is depended upon for the raising of crops. The tillable area of the Territory is estimated at 12,000 square miles. The land is easily broken and cultivated, being generally free from stones and other obstructions. In exceptional seasons the natural rain-fall is sufficient to produce a growth of grain and vegetables, but irrigation ditches and a reliable supply of water are necessary to insure the success of farming operations. During the last few years many companies have been incorporated in the Territory for the purpose of constructing irrigating canals and ditches. Many of these enterprises are now in successful operation. In a period of four months during the year 1886, within the district comprising the southeastern portion of Laramie County, there were recorded the articles of incorporation of over five hundred canals and ditches, extending over 1,000 miles in length and covering at least 100,000 acres of land. The works of the Wyoming Development Company, in the same county, include two canals, 29 and 37 miles long, respectively, and from 20 to 25 feet wide; 19 miles of lateral ditches, from 6 to 12 feet wide, and a rock tunnel three-fourths of a mile long, with a flow of 1,500 cubic feet per second. This system, built at a cost of $500,000, reclaims 60,000 acres of desert land.

ALBANY COUNTY.

(Total area, 6,922 square miles; estimated forest area, 840 square miles.)

This is a long and narrow county, in the southeastern part of the Territory. The Laramie and Medicine Bow ranges occupy large areas in the north central, eastern, and southern portions.

The North Platte and Big Laramie Rivers are the principal water-courses. These, together with numerous tributary streams having their sources in the snowy mountains of the region, furnish an abundance of water for irrigating purposes.

The forest growth consists mainly of Yellow and White Pine, Tamarack or Lodge-pole Pine, Red Cedar, and Aspen. It is mostly confined to the mountain slopes and foot-hills. The heaviest bodies of timber are found in the central and southwestern parts of the county.

Between Fort Fetterman and Laramie Peak on the La Bonte and Horseshoe Creeks, and on the Caspar Mountain, 50 miles west of Fort Fetterman, are large tracts of good saw timber. Along the North Platte and its tributary creeks are fine growths of Cottonwood and Box Elder.

Lodge-pole Pine (*Pinus Murrayana*) is the predominant forest tree along the range east of Laramie. Yellow Pine is common along the lower mountains, but does not have a dense growth. It is the largest and most valuable of the pines. White Pine (*Pinus flexilis*) grows near the timber line. A scattering growth of Red Cedar is found on the foot-hills. Of the two varieties of Cottonwood native to this region (*Populus monilifera* and *Populus angustifolia*) the latter is the most prevalent. It is estimated that one-quarter of the entire forest area is good timber. Upon northern slopes, after the original stock has been cut or destroyed, a second growth soon follows, consisting of Lodge-pole Pine, or species similar to the first growth. Forest trees are planted and cultivated to a very limited extent, with the aid of irrigation.

CARBON COUNTY.

(Total area, 13,526 square miles; estimated forest area, 1,360 square miles.)

This county is in the south central portion of the Territory. Its area is quite equally divided between mountains and plains. The Laramie Plains extend across its eastern border, and westward to the North Platte River. The principal mountain ranges are the Medicine Bow at the southeast, Sierra Madre at the southwest, and the Seminole and Rattlesnake in the west central portion. Spurs of the Big Horn and Laramie ranges penetrate the county at the northeast and north. The North Platte River, for a distance of about 200 miles, flows through the interior of the county. Many other streams tributary to the Platte, and the Powder River at the north, have their sources here. Upon all the mountains are coniferous forests, of greater or less extent, the most important being upon the snowy ranges of the Medicine Bow and Sierra Madre. The forest growth appears at altitudes ranging from 8,000 to 12,000 feet above sea-level, and consists, for the most part, of Yellow and White Pine, Tamarack or Lodge-pole Pine, White Spruce, and Aspen. Lodge-pole Pine is the predominant species. It grows from 2 to 14 inches in diameter. At high elevations in the Medicine Bow Mountains the White Spruce attains great size, the trunks of that species sometimes reaching a diameter of 6 feet. In sheltered places along French Creek, on the western slope of the same range, the Aspen grows very large, the bodies of the trees often being 2 feet in diameter. About one-half of the forest area is good timber, though not large, the trees having a tall and slender habit. Immense coal fields exist in this region and have been partially developed—a condition which ought to lessen the drain upon the forests for fuel.

CROOK COUNTY.

(Total area, 10,709 square miles; estimated forest area, 400 square miles.)

This county, which occupies the northeastern corner of the Territory, is in form an exact square, its sides being a little more than 100 miles in length. Its general surface features are rolling plains, the Black Hills and other minor ranges and hills occupying but a small portion of the county. It is fairly well watered for a plains region. The lands are adapted to grazing and limited farming operations, if irrigated.

The forest growth is scanty, consisting principally of Yellow Pine, Red Cedar, Oak, and Cottonwood. The Pine is found on the Black Hills, in the eastern part of the county, and on detached spurs in the southwestern portion. The Cedar and Oak have a scattering growth on the low hills, and the Cottonwood borders the streams.

About one-third of the timbered area is fully stocked. Forest fires have been very destructive, and after a fire a second growth rarely appears. As yet there are only five saw-mills in the county.

FREMONT COUNTY.

(Total area, 20,957 square miles; estimated forest area, 3,300 square miles.)

This is the largest county in Wyoming. It is situated in the northwestern part of the Territory and extends to both the eastern and western slopes of the main Rocky Mountain range.

The topography of the region is greatly varied; mountains, plains, valleys, and swift-running streams are leading features. "The Shoshone and Wind River Mountain ranges extend from the north along the west limit of the county to the Sweetwater and Rattlesnake Ranges in its southeastern corner. The Wind and Sweetwater Rivers and tributaries of the Green run through it, and the Big Horn River forms a part of its eastern boundary." In the northeastern part of the county there is a broken and open country. At the southwest the Colorado Desert occupies a considerable area.

The most extensive (though not the heaviest) bodies of timber in the Territory are found in this and the adjoining county of Uinta.

From one-third to one-half of the forest area is fully stocked, good for timber. Yellow and White Pine, Lodge-pole Pine, Red Cedar, and Cottonwood are the predominant species. The best timber grows on the higher elevations. An open growth of Pine and Cedar covers the foot-hills. Dense groves of Cottonwood are found on the bottoms, along the Grey Bull and Big Horn Rivers and their tributaries.

JOHNSON COUNTY.

(Total area, 11,121 square miles; estimated forest area, 1,800 square miles.)

Johnson County is in the north central portion of Wyoming, bordering on the Montana line.

The Big Horn range of mountains, which is about 100 miles long by 40 to 50 wide, enters at the northwest and extends nearly through the county to its southern border.

These mountains are quite high and rugged, and carry snow upon their summits most of the year. The Big Horn River, which forms the western boundary of the county, and the Powder River, flowing near its eastern margin, are the most important streams. Many tributary creeks traverse the county in other directions. The surface of the eastern and southwestern parts is rough and broken. The country lying at the eastern base of the mountains is undulating and susceptible of irrigation. The bottoms along many of the streams are from one-fourth of a mile to a mile in breadth and are well adapted to agriculture.

The forest area, which is comparatively large, is confined to the Big Horn Mountains. The principal species of trees are the Yellow and White Pine, White Spruce, Aspen, Oak, Cottonwood, Box Elder, and Willow. The last three grow on the narrow bottoms bordering the streams. White Pine is the predominant coniferous species. There are from ten to twelve saw-mills in the county, and the timber is being rapidly cut. The annual lumber product is about 8,000,000 feet, besides 2,000,000 shingles and 300,000 laths; all of which is for local use.

LARAMIE COUNTY.

(Total area, 11,200 square miles; estimated forest area, 80 square miles.)

This county occupies the southeastern corner of Wyoming and is the seat of the Territorial capital, Cheyenne. About three-fourths of its area is a rolling plain, and, excepting some of the bottom lands along the streams, it is a grazing region. At the western side the spurs and foot-hills of the Laramie range of mountains cover a small portion of this county. The North Platte River flows in a diagonal course through the central part, and is the principal stream. A number of smaller rivers and creeks traverse the county.

The timbered area is extremely limited. Some scattering Pine is found on the foot-hills in the western part, and narrow belts of the Cottonwood along the North Platte, Laramie, Chugwater, and other streams. There is no timber of sufficient size for the manufacture of lumber.

SWEETWATER COUNTY.

(Total area, 10,550 square miles; estimated forest area, 40 square miles.)

This county is situated in the southwestern part of the Territory and is, to a large extent, barren and worthless for agricultural purposes. The northwestern corner includes a portion of the Colorado Desert, the central portion is mostly sandy and abounding with sage brush, while at the southeast is the Red Desert. The southern part, bordering on Colorado and Utah, is broken and sterile. The Green River flows through the western part of the county. Small streams start from the mountains at the northeast, but are soon lost in sandy wastes. The county is rich in coal, iron, and other minerals, and parts of it afford good grazing for stock.

There are no forests in the county. A little Pine and Spruce upon the northern and southern borders, an open and scattering growth of Cedar and Aspen on some of the ridges, and a fringe of Cottonwood along a portion of Green River, comprise the timber supply.

UINTA COUNTY.

(Total area, 12,140 square miles; estimated forest area, 2,400 square miles.)

Exclusive of Yellowstone Park at the north, Uinta County extends across the entire western border of the Territory. Three-fourths of its area is mountainous. The principal ranges are the Wind River, at the northeast, and the Teton, Snake River, Salt River, and Bear River ranges along the west line. The county has some fertile valleys, and is well watered by numerous small streams flowing from the mountains.

The forest area is large, but the timber is inferior in size and quality. White and Lodge pole Pine are the predominant species. They grow tall and slender, the trunks of the largest trees rarely exceeding 15 inches in diameter. A scattering growth of Red Cedar appears upon many of the low hills.

Lumber and charcoal are manufactured here to some extent. Large deposits of mineral coal are being worked in the southern part of the county.

YELLOWSTONE NATIONAL PARK.

(Total area, 3,250 square miles; estimated forest area, 1,840 square miles.)

This Government reservation is situated in the northwestern corner of Wyoming, and embraces a section of the main Rocky Mountain range nearly 60 miles square. The region is noted for its magnificent scenery. Its snow-clad ranges and peaks are partially clothed with pine forests, and overlook a number of beautiful lakes of great depth and clearness. Here are found the sources of rivers tributary to the Missouri, the Columbia, and the Colorado of the West—great water ways which seek the sea in opposite directions.

The predominant forest trees are White and Lodge-pole Pine. Occasionally, upon the lower slopes of the mountains, the Yellow Pine appears. Scattering growths of Red Cedar and Aspen are also found upon the foot-hills, and Cottonwood along the streams.

As this reservation is under the special supervision of officers of the General Government, it is presumed the forests, as well as other natural features of the region, will be preserved.

COLORADO.

The State of Colorado occupies a central and commanding position upon the great interior plateau, and within its borders are grouped the highest and most rugged of the Rocky Ranges. It has been justly termed "The Crest of the Continent." Amid its snowy summits and forest-clad mountains rise many of the great streams constituting the water systems of the West and South. Its average or mean elevation (7,000 feet above sea level) is greater than that of any other portion of North America. The neighboring Territories have a mean elevation as follows: New Mexico, 5,600 feet; Wyoming, 6,000 feet; Utah, 5,700 feet; Idaho, 4,700 feet; Montana, 3,000 feet.

The State is regular in outline, nearly square, and embraces a superficial area of 100,200 square miles. Its two great natural subdivisions, plains and mountains, are separated by a north and south line nearly coincident with the one hundred and fifth meridian. Three-sevenths of the entire area lies east of that line, within the plains region, and is a high, rolling, semi-arid country, almost wholly devoid of timber, and insufficiently watered by the South Platte and Arkansas Rivers and their tributaries. At the base of the mountains it has an elevation of 5,000 to 6,000 feet; thence sloping gradually to the eastern border, where the altitude is 1,000 to 1,500 feet less. The western and larger division of the State includes in its eastern part the Main Range, or Continental Divide, and almost numberless minor ranges, spurs, and groups. Between these and the Utah line is a more open country, broken by extensive plateaus and mesas, detached mountain groups, isolated peaks, hills, and buttes. Large rivers traverse the region, bordered in places by broad and fertile valleys, and at other points confined within deep and narrow canyons.

"The parks of Colorado are a distinctive and remarkable feature of the mountain region, apparently the basins of former lakes upheaved and deprived of their waters by volcanic agency, with their original shape and situation at the foot of high mountains undisturbed, while their lowest depths are from 6,000 to 9,000 feet above the level of the sea. Many of these parks are small, being little valleys at the sources of single streams, or the beds of small lakes into which several streams from the surrounding mountains are emptied; yet there are four of these elevated valleys, the smallest of which extends 20 by 50 miles, and the largest 100 by 200, equal in size to some of the most important of the New England States. These are called the North Park, Middle Park, South Park, and San Luis Park."

In all these parks are rich grazing lands, and in many of them are large and productive agricultural areas.

The principal rivers of the State are the Arkansas and South Platte on the eastern side, which find outlet through the Missouri and Mississippi to the Gulf of Mexico; the Yampah, White, Grand, Gunnison, and Rio Dolores upon the Pacific slope, tributary to the Colorado River of the West; and the Rio Grande, flowing southward to the Gulf of Mexico. All of these rivers have their sources in, and are dependent upon, the central snowy ranges. It is instructive to note the preponderance of streams upon the western slope, where the forests are most dense, and where occurs the greatest precipitation of moisture.

The forests of Colorado are situated mostly in the western mountainous divisions at the higher elevations. A tongue of timbered land invades the mid-eastern portion for a distance of about 30 miles along the crest of the Arkansas-Platte divide; and another tract of wooded country extends for a short distance into Las Animas County at the southeast. The heaviest forest growth is in the north central, central, and southwestern parts of the State. Some of the finest timber is found at the southwest, in La Plata and Archuleta Counties. Much of it grows on high, rolling plateaus; the trees are tall and straight; but little undergrowth exists; and should the land ever be cleared, it is unlikely to revert to forest, and would be suitable for agriculture or pasturage.

The forest flora of the State is embraced in the following list:

Yellow Pine (*Pinus ponderosa* var. *scopulorum*).
White Pine (*P. flexilis*).
Black or Lodge-pole Pine (*P. Murrayana*).
Fox-tail Pine (*P. Balfouriana* var. *aristata*).
Piñon or Nut Pine (*P. edulis*).
White Spruce (*Picea Engelmanni*).
Black Spruce (*P. nigra*).
Silver or Blue Spruce (*P. pungens*).
Red or Yellow Fir (*Pseudotsuga Douglasii*).
White Fir (*Abies concolor*).
Balsam (*A. Subalpina*).
Red Cedar (*Juniperus Virginiana*).
Juniper (*J. occidentalis* var. *monosperma*).
Juniper (*J. communis* var. *alpina*).
Cottonwood (*Populus monilifera*).
Black Cottonwood (*P. angustifolia*).
White Cottonwood (*P. Fremontii*).
Balm of Gilead (*P. balsamifera*).
Aspen (*P. tremuloides*).
Box Elder (*Negundo aceroides*).
Dwarf Maple (*Acer glabrum*).
Locust (*Robinia Neo-Mexicana*).
Mesquit or Honey Locust (*Prosopis juliflora*).
White Oak (*Quercus grisea*).
Scrub Oak (*Q. undulata* var. *Gambelii*).
Wild Plum (*Prunus Americana*).
Chickasaw or Hog Plum (*P. angustifolia*).
Wild Cherry (*P. Pennsylvanica*).
Mountain Mahogany (*Cercocarpus parvifolius*).
Black Thorn (*Cratægus tomentosa*).
Willow (*Salix lasiandra*).
Sand-bar Willow (*S. longifolia*).
Black Birch (*Betula occidentalis*).
Black or Speckled Alder (*Alnus incana*).

Yellow and White Pine and White Spruce are the predominant species, and are the most useful for general purposes. The Spruce (known locally as "Red Spruce," from the color of its wood) grows at higher elevations than the Pines and is not so plentiful or so easily obtained as the latter. Its wood is superior to that of the others. Piñon, though not forming extensive forests, has quite a wide range in the State, and is largely used for fuel and the manufacture of charcoal.

The consumption of lumber in the State during the last twelve months is estimated at 120,000,000 feet, B. M., two-thirds being native timber and one-third imported. For building purposes native Yellow and White Pine and White Spruce, and White Pine from Michigan and Wisconsin are largely used. For finishing and cabinet-work the

White Pine and hard woods of the central, western, and eastern States are preferred. Southern Pine is extensively used for flooring. Redwood from the Pacific coast is used to a limited extent for some purposes. Red Cedar shingles are shipped to Colorado from both the east and west. Long timbers for bridges, railway construction, etc., are not easily obtained here, nor are they equal in strength and durability to those procured at outside points. The Colorado Midland Railway Company has recently made purchases as follows:

Oregon Pine, 3,000,000 feet, B. M.; Texas Pine, 500,000 feet, B. M.; New Mexico Pine, 2,500,000 feet, B. M.

It is hoped that when more direct railway communication is established between this region and the heavily timbered portions of the Pacific coast the lumber supplies of the latter will be more freely drawn upon, lessening to that extent the demands upon the scantily timbered districts of the mountains.

The agricultural interests of the State are rapidly increasing, and have become of the first importance. The dependence of farming operations upon irrigation systems, and the important relations existing between them and the streams and forests of the mountains, are nowhere more apparent than in Colorado. It is estimated that the entire canal system of the State embraces something over 800 miles of large canals completed, about 200 miles projected, and about 4,000 miles of canals of smaller size. The Del Norte Canal, in the San Luis Valley, is the largest irrigating canal in the United States. "It is 65 feet wide on the bottom at the head-gate, carrying water 5½ feet deep, with side slopes 3 to 1, making the top width at water-line 98 feet. Four miles from the head it is divided, the larger branch being 42 feet wide on the bottom, and the smaller branch 38 feet wide. There are about 50 miles of main channel. It carries something over 2,400 cubic feet of water per second and is calculated to irrigate over 200,000 acres. The extent of territory in the State covered by the entire distributive system is, approximately, 40,000 square miles, constituting the bulk of the arable land. The system has cost in construction about $12,000,000.

In mileage of canals and acreage irrigated, Colorado more than doubles any other State; its works are the greatest, the most permanent, and the most rapidly extending.

This State is the only one which has a constitutional clause requiring the enactment of laws to prevent the destruction of forests and to keep them in good preservation. Until within the last three years, however, but little heed has been paid to that provision. In the summer and autumn of 1884, by a series of published articles, the attention of the people was drawn to the urgent need of protecting the forests of the State and enlarging their area. In November of that year a State forestry association was formed, which has done a good work and is still in active existence. In the winter of 1884–'85, by legislative enactment, the office of State forest commissioner was created, the duties of the office defined, and the county commissioners and road overseers throughout the State constituted forest officers in their respective localities, with special duties relating to the protection of forests. At the same time acts were passed imposing penalties for the willful or careless setting of forest fires, for failure to extinguish camp fires, etc., and requiring the posting of notices in public places warning persons against the violation of the law. At the recent session of the legislature (1886–'87) the law was made more stringent in some respects, the State forest commissioner was given a salary and traveling allowances, and Congress was memorialized upon the subject of transferring to the State the custody or control of the public forest lands within her limits. Altogether, Colorado has made very substantial and gratifying progress in forest matters.

ARAPAHOE COUNTY.

(Area, 4,700 square miles.)

This county is in the northeastern part of the State. It has no forest land. Its area consists mainly of gently rolling prairie. The western half of the county is quite well watered by the South Platte River and its tributaries. An extensive system of irrigation renders productive large bodies of land.

ARCHULETA COUNTY.

(Area, 1,026 square miles; estimated forest area, 450 square miles.)

This county is situated on the southern line of the State, and near its western border. Its surface is mountainous, but includes fertile valleys. The forest land is well distributed; every square mile is said to have timber enough for needed purposes.

The timber is chiefly Pine, of good quality; 12 per cent. is brush of promising growth; very little has been made waste by burning. The principal species are Pine, Cedar, Spruce, Cotton-wood, Piñon, Oak, Aspen, and Willow; Yellow Pine predominates.

After the destruction of the forests, the chances of their renewal are slight. On mountain ranges sloping to the north, Aspen usually follows fires as a second growth.

No changes are noticed as yet in the volume and flow of water in streams; springs and running streams abound.

Indians start fires to drive the game from some places; they also strip the bark from standing Pine trees to obtain a pulp of sweetish taste that accumulates between the bark and the wood. It is stated that they cause more destruction of timber than all other agencies combined.

The water for irrigation purposes is deemed insufficient.

BENT COUNTY.

(Area, 9,070 square miles.)

Bent County lies upon the eastern border of the State, and is wholly within the plains region. It is inadequately watered by the Arkansas

River and its tributaries. There are no forests in the county. Considerable land is being brought under cultivation, with the aid of irrigation.

BOULDER COUNTY.

(Area, 768 square miles; estimated forest area, 275 square miles.)

This county is situated in the north-central part of the State. It is bordered on the west by the main Rocky Mountain range, and is well watered by streams tributary to the South Platte River. The western half is mountainous and timbered; about one-third of the timber is good, and one-fourth burned over, with a young growth following. The principal arborescent species are, Yellow and White Pine, Spruce, and Fir. The timber is scattered over nearly all of the mountainous portions of the county, while along the foot of the range it is quite dense. After forest fires, the second growth usually consists of wild Maple, Alder, and shrubs.

The eastern third of the county is rolling and valley-land, most of which is suitable for farming purposes.

CHAFFEE COUNTY.

(Area, 900 square miles; estimated forest area, 500 square miles.)

This county, which occupies a central position in the State, is almost surrounded by mountain ranges. It contains a large proportion of farming and grazing land, and is abundantly watered by the Arkansas River and its tributaries.

About two-thirds of the county is timbered. Near the summits of the mountains is Spruce, below them Yellow Pine, and in the foot-hills and mesas Piñon and Scrub Pine; along the streams are Willow—(Black or Narrow-leafed), Cotton-wood, and Aspen. The timber land is mainly situated along the eastern slope of the Continental Divide, which forms the western boundary of the county, and in the range of hills between the South Park and the Arkansas River. The timber in the more open valleys of the river is largely Piñon, great quantities of which have been cut and converted into charcoal for the use of the smelters of Leadville, Pueblo, and Denver. There are a number of saw-mills, and a great many railway cross-ties are being cut. This consumes the best part of the timber.

CLEAR CREEK COUNTY.

(Area, 450 square miles; estimated forest area, 200 square miles.)

This is pre-eminently a mountainous county. The main snowy range, with an altitude of 14,000 feet and more, extends along the entire western boundary. It sends off lofty spurs, many of the peaks rising far above the timber line, and these, in parallel ranges, traverse the county from west to east. The surface of the county, therefore, is almost wholly covered with lofty mountains, with narrow valleys between.

The county was originally well timbered, the valleys and mountain sides, up to the timber line, being generally covered with a fine growth of Pine, Balsam, and Spruce. Much of this has been cut off, and more has been destroyed by forest fires, but the supply is thought sufficient for some years to come, if carefully husbanded. It is believed that the careless and willful destruction of timber might be prevented by speedily and surely punishing offenders.

The amount of water carried by the streams varies somewhat from year to year, being dependent upon the snow-fall. The average amount for a given period of years would remain about the same. Owing to the cutting of timber on the mountains the snow melts more rapidly than formerly, thus causing a greater flow of water in the early summer and less later.

CONEJOS COUNTY.

(Area, 1,320 square miles; estimated forest area, 300 square miles.)

This county is in southern Colorado, bordering on the Territory of New Mexico. The western half of the county is mountainous; the eastern half lies in the San Luis Park, the surface having a gradual descent to the Rio Grande River. About three-eighths of the county is forest land, located in the range in the western part. Not more than one-eighth of the forest land is well stocked with timber; one-eighth is covered with Aspen and one-fifth is made waste by burning. The forest growth remaining is mostly Pine, with some Spruce and Aspen. Along the streams in the valleys are found Cottonwood and Willow.

Fire destroys more timber in one year than would be consumed by other causes in ten. After the forests have been destroyed there is very little chance for their renewal.

As the trees are cut off or burned there is less water in the streams, the snows melting earlier in the spring. It is suggested that the supply of water might be materially increased by the beaver. This little animal, by a system of dams and canals, stores immense quantities of water in the early summer, which comes down later in the season. Could the beaver be protected by law on many streams there would be no need of artificial storage.

COSTILLA COUNTY.

(Area, 1,450 square miles; estimated forest area, 450 square miles.)

This county is also on the southern border of the State. Its eastern boundary is formed by the Sangre de Christo and Culebra ranges. The Rio Grande River borders it on the west. The San Luis Park extends through a large portion of the county.

The forests are situated in the northern and eastern parts, on the mountains and foot-hills. About one-half of the timber is Piñon and

Cedar, one-fourth Pine and Spruce, and the remainder consists of burned tracts and belts of Cottonwood along the streams. The trees are generally inferior in size, only a small proportion being suitable for lumber.

Fire is the most destructive agent threatening the forests; railroads next. Some lumber is made, but most of the saw-timber has been consumed. After the forests have been destroyed by fire it is only on the northern hill-sides that the original growth starts again. Aspen generally follows after fire. Only in favorable situations do Spruce and Pine grow again.

During the last twenty years the forest growth in this county has not been sufficiently disturbed to affect the volume and flow of the stream.

CUSTER COUNTY.

(Area, 750 square miles; estimated forest area, 200 square miles.)

This county, which lies in the south central part of the State, is bordered on the west and south by the Sangre de Christo and Greenhorn ranges, respectively.

The forests are situated mainly at the west and south, in the mountains. Some timber is also found on the north and east sides. In the western part of the county, at the foot of the range, there is an open valley, about 9 miles wide, running the whole length of the county. The only timber there consists of a few Cottonwoods and Willows along the streams. Pine, Piñon, and Cedar are found on the low hills; at higher elevations are Spruce, Balsam, and Aspen. Very little has been made waste by burning. The best timber has been cut off for use at the mills. The special dangers threatening the forests are fires and lumbering. On the range a second growth will start, usually of the same kind as the first. On the low hills, especially after fires, there is no second growth.

No changes have been observed in the flow and volume of streams at their headwaters. In the lower lands floods are now frequent from cloud-bursts or sudden rains.

DELTA COUNTY.

(Area, 1,150 square miles; estimated forest area, 500 square miles.)

This county is situated in the western part of the State, in a region of plateaus and mesas. The Gunnison and Uncompahgre are its principal rivers.

The timber consists of Pine, Piñon, Cedar, and Spruce, the several kinds being about equally distributed over the slopes of the Grand and other high mesas along the western, northern, and eastern borders of the county. There are about 10,000 acres of Cottonwood along the Gunnison River and its tributaries.

The average rain-fall is thought to be increasing. The danger of forests being destroyed by fire is not considered imminent, as they are situated at a high altitude, and where there is considerable humidity.

DOLORES COUNTY.

(Area, 800 square miles; estimated forest area, 150 square miles.)

The surface of this county is much broken. It includes mountain ranges, high mesas or table-lands, and narrow valleys bounded by box canyons, or gently sloping hill-sides. It is well watered by the Dolores River and its tributaries.

The forest lands are situated chiefly in the eastern half of the county. About two-thirds of the timber is Yellow Pine and Spruce; the remainder is Piñon and Aspen. Only a small percentage of the timber is suitable for lumber, the trees being small and stunted. Fires and the consumption for mining purposes are the special dangers threatening the forests. It is said that after the forests have been destroyed Nature speedily reproduces them, the high altitude and moist atmosphere contributing to that end.

DOUGLAS COUNTY.

(Area, 850 square miles; estimated forest area, 300 square miles.)

About two-fifths of the area of this county has a scattering growth of timber, situated mainly on the north side of the Arkansas-Platte Divide and in the mountains to the west. The timber on the divide has been cut, but considerable young timber is now growing. In the mountains fully one-half of the timber has been burned. The forest growth remaining, principally small, rarely exceeds 15 inches in diameter. Pine and spruce are the predominant species. Lumbering has been the greatest destroyer of timber. A new growth is appearing on some of the old burned tracts. This growth is usually Pine on the south side of the mountains and Spruce on the north side.

The volume and flow of water in the streams have been affected by various means; such as forest fires, or cutting off the timber at the head-waters of the streams, or of dense growths of timber and underbrush elsewhere. Wherever the forests have been cleared off, the snow melts rapidly, giving a heavy flow of water in early spring, and an insufficient flow in the summer.

EAGLE COUNTY.

(Area, 1,750 square miles; estimated forest area, 300 square miles.)

This county is situated in the northwestern part of the State. The surface is mountainous, and includes fertile valleys suited for many kinds of grain and vegetables, especially those that mature in a short season. Mining and stock-raising are the chief industries.

The forests are found in the eastern part of the county. Two-fifths are said to be good timber, one-fifth brush, and two fifths made waste by burning. The forest trees are of straight and thrifty growth, of medium size, but mostly too small for lumbering purposes. The White Pine and White Spruce predominate.

Fire is the special danger threatening the forests. When the forest is destroyed by fire the ground is usually burned so deeply that all fertility is destroyed. The second growth is usually the same as the first, when the land has been burned. After fire, Aspen grows first, then White Pine, and later Spruce.

ELBERT COUNTY.

(Area, 5,800 square miles; estimated forest area, 100 square miles.)

The county is situated in the eastern part of the State, in the Plains region. The western portion is broken, and is fairly well watered by tributaries of the South Platte River.

The limited amount of forest land in this county is found mostly in the northwestern part. Lumbermen have cut all the good timber, and the present forest growth is small and scattering. Pine is the predominant species.

It is stated that floods have become more frequent since the destruction of the timber.

EL PASO COUNTY.

(Area, 2,650 square miles; estimated forest area, 500 square miles.)

This county occupies a central position in the State. The eastern half (south of the Arkansas-Platte Divide) consists of undulating plains, with no timber and very little water. The elevation at the east line is 4,500 feet, reaching to 6,000 feet in the center, at the base of the Pike's Peak range. The western portion, and also that lying north of a line between townships 12 and 13, south, is very mountainous, reaching an elevation of 14,167 feet at the summit of Pike's Peak, 9,250 feet at the crest of the Hayden Divide, and 8,500 feet at the highest point of the Arkansas-Platte Divide. The western and northern parts of the county, above an elevation of 5,500 feet, are in most parts well timbered with Pine, Spruce, Fir, etc. The heaviest timber is found at an altitude of 6,000 to 10,000 feet; that below 6,000 feet is mostly Yellow Pine, Piñon, Scrub Oak, and Cottonwood.

FREMONT COUNTY.

(Area, 1,450 square miles; estimated forest area, 450 square miles.)

About three-fourths of the area of this county is mountainous. The county is drained by numerous streams, all of which flow into the Arkansas River. The forest land is situated mainly in the northern and western portions. There is very little available timber large enough for lumber, and no brush of promising growth. The forest growth is Piñon and Pine, White Spruce, Cottonwood (on margins of streams) Aspen, Scrub Oak, Box-Elder and Wild Maple. Piñon and Pine predominate. The Piñon and Oak make excellent fuel; the former is also used extensively in the manufacture of charcoal.

Charcoal burning is the principal danger threatening the forests. The prospects of renewal after the forests have been destroyed are very poor. In the mountains the second growth is usually Aspen.

GARFIELD COUNTY.

(Area, 7,250 square miles; estimated forest area, 800 square miles.)

This large county is situated in the plateau region of western Colorado. It is watered by the White and Grand Rivers and their numerous tributaries.

From the Great Hogback west to the head-waters of Roan and Douglas Creeks, are low sandstone hills, covered with stunted Piñon and Cedar. The divide between Grand and White Rivers bears scattering bunches of Spruce and Aspen, the latter predominating. East of the great Hogback are large forests of Fir, White Spruce, and Pine; also, in the immediate vicinity of White River are groves of very large Aspen. Dwarf Piñon and Cedar are found near Carbonate and west to the great Hogback, on the divide between Grand and White Rivers. The finest timber is said to be situated in the northeast part of the county, on the White Pine Plateau. In the higher altitudes there are some large bodies of timber, mainly White Spruce.

Fire is the principal cause of the destruction of timber in this county. The law requiring the extinguishment of camp-fires should be strictly enforced. The statement is made that the Ute Indians, who roam at large and make their summer headquarters in the best timber, are responsible for some of the forest fires. The chances for renewal, after the forests have been destroyed by fire, are few. Aspen, if anything, springs up after fire.

GILPIN COUNTY.

(Area, 140 square miles; estimated forest area, 50 square miles.)

This county is situated in the north-central part of the State, upon the eastern slope of the main range. The eastern portion is rugged and mountainous, embracing Bear Mountains, South Hill, etc. In the central and northern part are low foot-hills: the western part rises to the summit of the range; and the southern part rises from North Clear Creek 2,000 to 3,000 feet to the summit of the ridge between the two forks of Clear Creek, which forms the southern boundary of the county.

There is but little timber of importance in the county; it has nearly all been cut off for mining purposes and fuel. That which is now used is brought from the extreme western part of the county, at the head of North Clear Creek. The principal green timber is in the vicinity of Bear Mountains, but it will not much exceed 1 square mile in area. A new growth, however, is rapidly springing up over about one third of the county. Of the forest trees now remaining, White Pine predominates.

There are no irrigating ditches in the county, and no farming land except small areas along the creeks and gulches, which in general require no irrigation. The volume of water in the streams has diminished to a considerable extent and become more irregular in flow, partly on account of the failure of springs, resulting from deep mining, but mainly because of the clearing off the forests. As the bare slopes can not absorb and retain the rain-fall, heavy floods occur at some seasons (summer) and there is excessive dryness at others.

GRAND COUNTY.

(Area, 1,800 square miles; estimated forest area, 700 square miles.)

This county is situated in north-central Colorado. A large portion of its area is covered by Middle Park, in which are found the sources of the Grand River. These streams furnish an abundant water supply. The forests of the county are situated upon the surrounding ranges and upon the mountain spurs projecting into the Park. About three-fifths of the timber is good for lumbering purposes; one-fifth is brush and saplings of promising growth, and the remainder has been made waste by fire. A peculiarity of this district is that burned areas are soon retimbered with the original species. Sometimes the second growth is Aspen.

The timber here is better than the average of Rocky Mountain timber, the trees running from 8 inches to 4 feet in diameter of trunk, from 25 to 75 feet in length, and suitable for lumber, shingles, etc. The principal species are Pine, Spruce (three varieties), Fir (two varieties), and Aspen; Pine predominates. Most of the timber is at present used as logs and poles, but little having been sawed into lumber.

"At the high altitude of the forests in this county, 8,000 to 11,000 feet above sea-level, timber growth is necessarily slow. In some parts of the forests snow lies until June, and in many portions until July. I can point out areas that had been burned over a few years previous to 1863, and upon which the new pine growth was then just started, or but a few feet high, which are now thickly covered with trees 10 or 12 inches in diameter and from 30 to 50 feet in height. These are in the middle of the Park. The spruce forests at high altitudes are seldom burned, and I can not speak so confidently of their reproduction. We have had no extensive fires for several years."

There are no irrigating ditches in the county, except a few very small and short ones belonging to individual ranchmen.

GUNNISON COUNTY.

(Area, 4,000 square miles; estimated forest area, 1,200 square miles.)

This county is irregular in outline, and covers a large area upon the western slope of the main range. It is bordered on the north by the Elk Mountains. The Gunnison River and its numerous tributaries constitute the water system.

The forests are situated mainly on the mountain slopes at the north and east. The principal trees are Pine, Spruce, Cedar, and Aspen. About one-fourth is brush, and as much more has been burned over. No portion is fully stocked. The trees are usually 3 to 18 inches in diameter. Pine and Spruce predominate. Cottonwood and Alder grow along the streams.

Fire is the principal destroyer of the forests. The renewal is slow but steady. The second growth is usually the same as the first, except after fire, when Aspen follows.

No particular change has been observed in the flow and volume of water in the streams. The entire county is well watered. There is a heavy fall of snow in the winter, and copious rain-fall in the summer.

HINSDALE COUNTY.

(Area, 1,440 square miles; estimated forest area, 450 square miles.)

This county is situated in the southwestern part of the State. It is drained in the northern portion by the head-waters of the Lake Fork of the Gunnison River and Henson Creek; in the middle part by the head-waters of the Rio Grande River; and in the southern portion by some of the tributaries of the San Juan River. The main range, or Continental Divide, crosses the county twice, in an east and west direction.

Timber grows in all of the valleys (which lie at an altitude of about 7,000 feet) and on the hillsides and mountain slopes, to a height of 11,000 feet. White Spruce, White and Yellow Pine, and Aspen are the principal species. Spruce and Aspen predominate. Only a small proportion of the forest trees are large enough for lumber.

No changes are observed in the streams, although without doubt the forests have a beneficial effect on the water supply. The difference here between high and low water is considerable, and the rise and fall is quite gradual. Heavy snows have occurred during the last three winters, resulting in plenty of water in the streams through the spring and summer months.

HUERFANO COUNTY.

(Area, 1,160 square miles; estimated forest area, 250 square miles.)

This county is situated in southeastern Colorado. Upon its northwestern, western, and southern borders are mountains and foot-hills covered, to a greater or less extent, with Pine, Spruce, Fir, Cedar, and

Aspen. These portions also include fertile valleys and fine grazing lands. In the central parts of the county are low hills, covered with Piñon and Cedar; also table-lands and valleys suitable for agriculture. In the eastern and northeastern portions are plains, on which are found scattering Piñon and Cedar. It is estimated that one-fourth of the forest land is fully stocked—good for timber; one eighth brush of promising growth, and one-eighth made waste by burning.

Pine, Piñon, and Cedar are the leading species. Brush and dwarf trees (mainly Cedar) are scattered in clumps over the whole county, but the heavy timber is mostly in the north and west, on the Greenhorn and Sangre de Christo Mountains. It is stated that less than one-hundredth part of the forest area is stocked with trees fit for timber.

Forest fires are frequent in the mountains of this county, destroying great quantities of timber.

JEFFERSON COUNTY.

(Area, 760 square miles; estimated forest area, 175 square miles.)

This county lies in the north-central part of the State, to the eastward of and at an average distance of 25 miles from the main Rocky Mountain range. In the eastern half of the county are plains and low foot-hills; the remainder is mountainous, and includes the narrow valleys of Coal, Clear, Bear, Elk, Cub, and Turkey Creeks, and the South Platte River.

"About 400 square miles in the mountains are two-thirds clad with forest. Not over 150 square miles abound in good timber. About 40 square miles is burned, dead, or wasted timber land; the rest is cleared or covered with young Poplar, Pine, or Spruce. The proportion of forest to other lands is about one-fifth."

The principal species of forest trees are Yellow, Fox-tail, and Scrub Pine, White Fir, Douglas Fir, Piñon, Cottonwood, Aspen, Hackberry, and Box-elder.

"Fires have destroyed in twenty years more timber than has been used in that time for lumber and fuel. The only protection possible is by a skillful body of forest police, to be established by the State, either alone, or in co-operation with the General Government. Such a police force should not only prevent destructive fires, but should have rigid supervision of mills sawing lumber on public lands. There should be penalties for the careless use of fire by hunters, mill-men, and others. There is a feeling of general indifference, unless aroused by self-interest, concerning such fires. No one should be allowed to waste the forests any more than other public property.

The chances for the renewal of forests are good, if fires are prevented from burning the waste and remnants of lumbering and clearing. The second growth is Aspen, the two kinds of Pine common everywhere, and Douglas and White Fir. After fires follow Aspen, with low Vine Maples and Willows; then common Pine.

For several years after 1860 I noticed changes in the volume of water in the streams. Since 1870 I have observed that a large growth of Pine and Poplar clothes the burned surface of the mountains on Bear and Clear Creeks, thus rendering sudden floods less violent than formerly. Since 1879 Clear Creek has had a more steady flow. I gauged that creek very closely from 1860 to 1872. I think the water supply in the months of August, September, and October of those years decreased. This was due, I think, to mining and the clearing of timber. Since that time a slight increase is perceived.

LAKE COUNTY.

(Area, 420 square miles; estimated forest area, 200 square miles.)

This county, of which Leadville is the county seat, is situated at a high elevation in the mountain ranges of central Colorado. Within its borders are a number of small lakes; and here also are the sources of the Arkansas River.

The forest lands of the county are mainly on the mountains forming its eastern and western borders. About one-fourth of the forest land is fully stocked, good for timber; one-fourth is brush of promising growth, and the remainder has been made waste by burning. Pine and Spruce are the predominant trees.

Very destructive forest fires have occurred in this county. After the destruction of the forests there is but little chance for their renewal.

LA PLATA COUNTY.

(Area, 4,000 square miles; estimated forest area, 1,500 square miles.)

This county, in southwestern Colorado, is 95 miles in extent from east to west, by 42 from north to south, and is situated on the southern slope of the San Juan Mountains. Its streams flow southward from fertile valleys, the principal ones being the Piedra, Los Pinos, Florida, Animas, La Plata, Mancos, Montezuma, and Dolores. The elevations are from 4,800 to 14,056 feet above the sea. The general altitude of the agricultural belt is 6,500 feet. The northern part of the county is rugged and broken, but the southern slope, dropping into long mesas and broad valleys, is well adapted to grazing and agriculture.

The northern and western portions of the county are well timbered. About 65 per cent. of the same is fully stocked; 25 per cent. is brush of promising growth, and the remainder made waste by burning.

The forest growth is Spruce and Fir, large and abundant, in the mountains; excellent Pine in the middle belt; and Cedar and Piñon in the south, interspersed with broad stretches of sage brush. After the destruction of forests, especially when caused by fire, their renewal is very slow.

The volume of water in the streams of the county has not changed, but high water is higher and low water is lower than formerly, due perhaps to loss of timber, causing less absorption and a more rapid flowing off of rain-fall. The forests cause a greater rain-fall, and absorb and more evenly discharge the water supply.

The snow-fall at Durango is often 6 feet in depth, beginning about the 1st of December and lasting until the 1st of April. In the mountains the fall in 1882–'83 was 45 feet, beginning on the 1st of October and lasting until the 1st of May.

LARIMER COUNTY.

(Area, 4,000 square miles; estimated forest area, 700 square miles.)

This county, lying immediately east of the main Rocky Mountain range, upon the northern border of the State, includes within its limits North Park. Its surface is greatly varied, embracing plains, mountains, and valleys. From range lines 69 and 70, in the eastern part of the county, the country rises rapidly to the summit of the Medicine Bow range, thence falls to the center of North Park, and rises again to the crest of the main range or Continental Divide. The prominent streams are the Little Thompson, Big Thompson, Cache la Poudre, Big Laramie, and the North Fork of Platte River.

The heaviest timber in the county runs through the central part, covering the Medicine Bow range and the northern and eastern slopes of the Continental Divide. Of the entire forest area about 300 square miles is fully stocked—good for timber, although the timber would not be considered first-class for commercial purposes, it ranging from saplings to trees 2 feet in diameter. White and Black Pine, White Spruce, and Hemlock are the predominant species. Cottonwood is found along the streams in the valleys, and Aspen in places on the mountain slopes.

Forest fires and the consumption and waste for railway purposes are the greatest dangers threatening the forests. There is very little chance for renewal after the forests have been destroyed. It is stated that 60 sections of forest land were burned over in the summer of 1886.

LAS ANIMAS COUNTY.

(Area, 6,500 square miles; estimated forest area, 500 square miles.)

This county, situated in the southeastern corner of the State, embraces four distinct topographical regions, viz:

First, the Park Plateau, which includes about 800 square miles in the extreme western part of the county, sloping from the Culebra Mountains eastward to Trinidad. Its elevation is 6,500 to 10,000 feet, and it consists of a sloping plain, broken by numerous canyons into narrow and rocky ridges.

Second, the Raton Hills, embracing a strip of basalt-covered Mesa, from 6 to 15 miles wide, and 120 miles long, extending along the southern boundary of the State, from Trinidad eastward. Elevation 6,000 to 9,000 feet; area, 1,000 square miles.

Third, the "Plains," comprising an area of 3,000 square miles, including nearly the entire eastern half of the county. This is a flat, nearly level country, sloping to the east. About 95 per cent. of its area has a rich, loamy soil; the remaining 5 per cent. is sandy. There is no water for irrigation. Elevation, 4,500 to 5,000 feet.

Fourth, the west-central division, or Purgatoire region, embraces an area of about 2,400 square miles, mostly of rough, broken prairie. Elevation, 5,000 to 6,300 feet. The drainage is to the northeast, by the Purgatoire and Apishipa Rivers, through deep, narrow canyons.

The forest lands are situated mainly in the western part of the county.

There are small forest areas in the Raton Hills, and along the canyon of the Purgatoire River. But a small proportion of the forest is fully stocked—good for timber, and probably one-sixth has been made waste by fire.

The principal species of trees are: On the southern slopes, at about 9,500 feet elevation, Aspen; from 8,000 to 9,000 feet, Yellow Pine and White Spruce; from 5,000 to 7,000 feet, Piñon and Cedar. On northern slopes, the range of each species is 1,000 feet lower. Along the streams are found Box Elder, Cottonwood, and Willow at various elevations; in the higher altitudes Pine and Spruce predominate.

Lumbering and fires are the special dangers threatening the forests. Fully one-third of all the Pine timber in the county has been cut and removed. Destructive forest fires are likely to occur from the dead tops and lops of trees cut for lumber and left scattered on the ground, although during the last few years such fires have been infrequent. After the forests have been destroyed, the chances for their renewal are very slight, except in comparatively moist situations above 9,000 feet elevation. The second growth is usually Aspen or Scrub Oak.

LOGAN COUNTY.

(Area, 3,000 square miles.)

This is a newly organized county, and is situated in the Plains region, in the northeastern corner of the State. The South Platte River flows through it. It has no forests. The county is being rapidly settled by a good class of farmers, and the subject of tree-planting is likely to receive due attention.

MESA COUNTY.

(Area, 3,850 square miles; estimated forest area, 275 square miles.)

This county is situated upon the western border of the State. It is watered by the Grand, Gunnison, and Rio Dolores Rivers, and their tributaries. The valley of the Grand River, which is here from 8 to 10 miles long and 30 miles wide, constitutes the main body of arable land in the county. East of Grand Junction, the Grand Mesa, 9,000 to 10,000 feet above the sea, and Plateau Creek Valley, 6,000 to 8,000 feet elevation, are covered mostly with Grass, Cedar, and Piñon. The county is broken by deep canyons, but affords good range for stock.

The main body of timber is on Piñon Mesa, the head waters of East and West and Rio Dominguez Creeks. South of the Grand and Gunnison Rivers, Yellow Pine and Spruce abound. A great part of the county, outside of Grand Valley, is covered with a scattering growth of Pine and Piñon. There is but little good timber. Along some of the streams are found Cottonwood and Box Elder. Aspen is plentiful in some localities.

MONTROSE COUNTY.

(Area, 2,040 square miles; estimated forest area, 640 square miles.)

This county adjoins Mesa County at the south and east. The Gunnison, Uncompahgre, San Miguel, and Rio Dolores are its principal rivers.

The forest land is situated mainly in the central part of the county. About one fifth of its area includes good timber. There is no brush of promising growth, and no portion made waste by fire. The trees are mostly Pine and Spruce of good size and quality. Aspen, Cottonwood, and Oak are small.

Lumbering is the special danger threatening the forests. If they are destroyed it is doubtful if they will ever be renewed.

OURAY COUNTY.

(Area, 190 square miles; estimated forest area, 110 square miles.)

This county is situated in southwestern Colorado, upon the western slope of the Main Range. The timber is pretty well distributed; it is said the best is found in the vicinity of Ouray, and in the northwestern part of the county. The forest growth consists of Yellow Pine, Fir, Piñon, Cedar, Cottonwood, Box Elder, Aspen, and Oak. Spruce and Aspen predominate in the mountains; on the hill sides, Cedar and Piñon.

After the forests have been destroyed the second growth, if any, is usually Cedar and Piñon. It is difficult for trees of any kind to start after fire has run over the ground.

PARK COUNTY.

(Area, 21,000 square miles; estimated forest area, 600 square miles.)

This county is in the geographical center of the State. A magnificent mountain park, called South Park, covers a large part of its area. On the west it is bordered by the Main Range. The principal streams which find outlet at the northeast are Tarryall Creek and the North and Middle Forks of the South Platte River.

The forest land of the county lies chiefly upon its western and northern borders. The timber consists largely of Pine and Spruce, the latter predominating. Of the forest area about one-fourth is good timber, and about one eighth made waste by fire. The remainder is composed of small growth and brush.

Concerning the effect of forests upon the water supply, it is stated that many of the small streams which were never known to fail in 1873–'84, and prior to that time, now fail about the last of July or the the first of August. It is believed by some that the snow-fall is lighter than in former years.

PITKIN COUNTY.

(Area, 1,090 square miles; estimated forest area, 540 square miles.)

This county is situated in west-central Colorado. It is bordered upon the east and southwest by the Saguache and Elk Ranges, respectively. It is abundantly watered by the Roaring Fork River and its tributaries.

The forests are well distributed over the county, the heaviest timber being found in the mountains. Pine, Spruce, Piñon, and Cedar are the principal species. They vary greatly in size; Pine predominates.

Fire, lumbering, and snow slides have been destructive to the forests; as yet railroads have caused little injury. The chances for renewal after the forests have been destroyed are poor. Scrub Oak, Aspen, Cottonwood, and various other small trees and shrubs constitute the second growth.

No changes have been observed in the volume of water in the streams. That is largely influenced by the fall of snow in the mountains.

PUEBLO COUNTY.

(Area, 2,350 square miles; estimated forest area, 125 square miles.)

This county, which borders the Plains Region in southeastern Colorado, is drained by the Arkansas River. About four townships in the southwestern corner are mountainous; the remainder of the county consists of plains much broken by bluffs or buttes, and deep, rocky ravines. Most of the county east, southeast, and north of the city of Pueblo lies in fair shape for cultivation.

The forest lands are mostly situated in the valleys of the Arkansas, Huerfano, Saint Charles, Fontaine qui Bouille, and in the western and southern parts of the county. A small portion, perhaps one-tenth, is fully stocked; good for timber.

Cottonwood is found in the valleys, Pine, Piñon, Cedar and Spruce in the high lands. The estimated area of forest lands includes the Cedar Bluffs, which are properly timber lands, and probably more valuable than any other, as the wood is used extensively for fencing. The Cottonwood timber is but little used. In the southwestern part of the county there are Pine and Spruce, but limited in amount; also some Oak and Aspen. That portion of the county has furnished the inhabitants with timber and lumber for more than twenty years.

The prospects for renewal of the forests after they have been destroyed are not promising, especially on the Cedar and Piñon lands. The second growth is usually the same as the original.

The flow of water in the streams is more intermittent than formerly

RIO GRANDE COUNTY.

(Area 1,300 square miles; estimated forest area, 275 square miles.)

This county is situated in the southwestern part of the State. The river Rio Grande del Norte enters near the northwest corner and flows through the county in a southeasterly direction. The valleys of the Rio Grande and its tributaries include good agricultural land, and the most easterly tier of townships are of like character. The remainder, and especially the western portion, is mountainous and covered with Spruce, Aspen, Pine, Piñon, and Cedar timber. The narrow-leafed Cottonwood grows abundantly and luxuriantly in the Rio Grande Valley, east of the South Fork.

Some years ago the Ute Indians destroyed many forest trees by removing the bark; they also caused many forest fires. Of late years lumbermen have taken more or less of the timber, and mining operations have been very destructive to forest growth.

The flow of water in the streams early in the spring is greater than formerly, probably owing to destruction of the forests, which occasions early melting of the snows.

ROUTT COUNTY.

(Area, 6,200 square miles; estimated forest area, 1,050 square miles.)

This county is situated in the northwest corner of the State. It is traversed from east to west by the Yampah River. This, with its tributary streams, constitutes its water system. The surface of the county is mountainous; the valleys for the most part are deep, and from one-half to one and a half miles wide. Several large parks are included within its boundaries.

The forests are found mostly in the eastern part and in the northwestern corner. The heaviest timber grows in the main range, extending along the eastern border of the county. About 25 per cent. of the forest area is good growing timber; 25 per cent. Aspen and Oak-brush, good mainly for fuel; and the remainder has been killed by fire.

The timber consists of Pine, Spruce, Balsam, Aspen, and, along the streams, Cottonwood. There are some fine trees, but of medium size. Pine and Spruce predominate.

SAGUACHE COUNTY.

(Area, 3,150 square miles; estimated forest area, 1,175 square miles.)

This county is situated in south-central Colorado. The Sangre de Christo Range forms its eastern boundary, and the Main Range passes diagonally through the western portion. The San Luis and Saguache Rivers and Cochetopa Creek are its principal streams.

The timber lands are mainly on the mountain ranges at the north and east. The forest growth consists of medium-size Pine, Spruce, Piñon, and Cedar, with Cottonwood in the valleys along the streams. About one-tenth of the forest area is fully stocked; good for timber.

Railroads and fires are the principal dangers threatening the forests. The replacement of forest growth is very slow. The second growth is usually the same as the original. The adoption of measures for the prevention of forest fires is strongly urged.

No particular changes in the flow and volume of water have been observed. High water has prevailed during the past three seasons.

SAN JUAN COUNTY.

(Area, 450 square miles; estimated forest area, 100 square miles.)

This county is situated in southwestern Colorado, in the San Juan Mountains, which form a part of the Main Range. Nearly one-half of the area of this county is above the timber line. Its elevation is from 8,400 to 14,000 feet above sea-level. It is drained by the Animas River and tributaries, excepting a small portion on the east, which is drained by the headwaters of the Rio Grande.

Timber is found on nearly two-thirds of the area below the timber line, which equals about one-third the total area of the county.

The forest growth consists principally of Pine, Spruce, Balsam, and Aspen, and is situated in the valleys and on the lower parts of the mountains. Fifty to 75 per cent. of the forest is said to be good timber, the trees having an average diameter of 12 to 24 inches. About 20 per cent. has been made waste by burning. There is very little brush or new growth.

The second growth, if any, is Aspen. Much of the timber is inaccessible. That which can be reached is likely to be used, as at present, for mining purposes and fuel. Lumber for building is now obtained from the adjoining county of La Plata.

The county lies at so high an altitude that there is scarcely any agriculture. The land in cultivation embraces about one and a half acres.

SAN MIGUEL COUNTY.

(Area, 1,375 square miles; estimated forest area, 260 square miles.)

This county lies in southwestern Colorado, its western extremity reaching the Utah line. Its surface descends toward the northwest. The principal streams are the Dolores River and tributaries, most of which flow through cañons, with precipitous banks. The San Miguel Mountains, a high range, form the east and southeastern boundaries of the county.

In the eastern part of the county is a dense growth of Spruce and Aspen, about 10 per cent. of the first named being good saw-timber.

The western part of the county is mostly mesa land, with scattering Piñon and Cedar, and in some parts a heavy undergrowth of Oak-brush. White Spruce is the predominant wood in the county.

The timber line varies from 10,500 to 11,000 feet. From the timber line down to about 9,000 feet the timber is chiefly Spruce and Fir; from 9,000 to 8,000, Aspen; 8,000 to 7,000, Aspen and Pine; 7,000 to 6,000, Aspen, Piñon, Scrub Oak, and Cottonwood. The mesas are mostly devoid of timber, except occasional groves of Aspen on the higher ones.

SUMMIT COUNTY.

(Area, 750 square miles; estimated forest area, 275 square miles.)

This county is situated in the north-central part of the State, on the western slope of the main range. The forests are located mainly on the mountain slopes at the east and south, and along the streams. The best timber is found in the mountain region. The forest growth consists of White Spruce, Balsam, Pine, Hemlock, Cedar, Piñon, Aspen, Narrow-leafed Cottonwood, Black Birch, Alder, and Willow. The Spruce, Pine, Hemlock, and Balsam grow large enough for lumber.

The special dangers threatening the forests are lumbering, railroads, and the careless use of fire by campers and mill employés. Quite a large part of the forest on the northeast side of Blue River has been burned over; also that on the Snake River, a tributary of the former. It is stated that before the settlement of the county forest fires destroyed 60 square miles of timber. There are in some places promising second growths, which are usually Pine, Spruce, and Aspen. After fire, Aspen usually follows, although in many places, on southern exposures, Pine is the most abundant.

As yet there is no noticeable change in the flow of water in the streams. The existing forest affords ample protection to the snow from solar heat, while the high altitude also prevents rapid melting. The lowest elevation in the county, near Blue River bridge at Green Mountain, is 7,600 feet.

For the more adequate protection of forests, it is said the people should be taught the importance of preventing forest fires, and that notices relating to the extinguishment of camp fires, etc., should be posted in all prominent places. People are more careless than malicious in allowing fires to spread.

"Keep up the cry, 'Preserve the forests,' and the people will heed it after awhile; you can not coerce, but it is possible to teach."

There is no land in the county suitable for agriculture, and there are no irrigating ditches.

WASHINGTON COUNTY.

(Area 2,220 square miles.)

This is a newly organized county, in the plains region of northeast Colorado. It has no native timber, unless it is a slight growth of Cottonwood along some of the streams.

WELD COUNTY.

(Area, 5,300 square miles.)

This county is situated in the northeastern part of the State. Its surface is mostly rolling plains, intersected by the South Platte, Cache la Poudre, Big and Little Thompson, and St. Vrain Rivers, and numerous small creeks. There is but little timber in the county except a scattering growth of Cottonwood along the Platte River, which extends through the county from west to east. There are small groves of Cottonwood and fruit and ornamental trees in union colony, Greeley.

NEW MEXICO.

The Territory of New Mexico extends from the thirty-second to the thirty-seventh degree of latitude, and from the one hundred and third to the one hundred and ninth parallel of longitude—embracing a superficial area of 122,500 square miles. It has the form of a parallelogram, with sides 350 miles in length. It is situated upon the southeastern border of the Rocky Mountain plateaus, and has an average or mean elevation of 5,600 feet above the level of the sea. The principal surface features of the country are extensive table-lands, or mesas, wide and sandy plains, mountains, foot-hills, and valleys.

The mountain system, which in Colorado is so intricate, including scores of rugged ranges and lofty peaks, becomes in New Mexico more simple. The ranges here are not so massive, are less in number and elevation, and more widely separated one from another. The mountain chains, diverging at the northern border, spread fan like over the Territory, and in broken lines flank upon either side the valley of the Rio Grande, which traverses the entire region from north to south. Detached groups and solitary mountains are seen at many points. Though all belong to the Rocky Mountain system, they are each distinguished by local names.

In the southeastern part of the Territory is the Llano Estacado, or Staked Plain, an elevated, arid region, which also extends into the adjoining State of Texas. The soil here is apparently barren, but produces abundantly the Mesquit (*Prosopis juliflora*), a small but deep-rooted and valuable tree or shrub. The land would yield good crops if water could be had for irrigation.

The general surface of the Territory has an elevation of about 5,000 feet in the northwestern portion, and thence descends toward the southeast, where at the lowest point it is only about 3,000 feet above sea-level.

"The fall of the Rio Grande, from the northern border of the Territory to the point where it cuts the New Mexico, Texas, and Chihuahua boundaries, is about 3,500 feet. The ranges generally rise from 2,000 to 5,000 feet above the mesas and high table-lands. Mount Baldy, 18 miles from Santa Fé, is 12,202 feet high; Mount Taylor, in the Sierra Mateo, is 11,200 feet high.

The Rio Grande, Rio Pecos, Canadian, and San Juan are the principal rivers of the Territory. The first rises in the mountains of southern Colorado, crosses the northern border of New Mexico at a central point, and follows a nearly direct course through the Territory to its southern boundary. This stream is not navigable at any point within the Territory. The valley of the Rio Grande, having an average width of 8 or 9 miles and a length of about 400, includes large areas of most excellent farming and fruit lands. The Rio Pecos, a large affluent of the Rio Grande, drains the mideastern and southeastern portions of the Territory, and the Canadian River and its tributaries the northeastern portion. The western part is drained by the San Juan, Zuñi, Gila, and other affluents of the Colorado River of the West. No lakes of considerable size have as yet been discovered in the Territory.

The water-courses of New Mexico, compared with those of her northern neighbor, Colorado, are few and of small volume. In the last-named State at least ten large and powerful rivers rise in the central mountain region, and, re-enforced by numerous tributaries, pass to and beyond the borders of the State. In New Mexico but two rivers, the Rio Grande and Rio Pecos, flow for a considerable distance within the limits of the Territory. The two other important streams, the Rio San Juan and Canadian, flow, respectively, through the northwestern and northeastern corners of the Territory. The San Juan River, as well as the Rio Grande, rises in southern Colorado.

"It is not uncommon for a river to be considerably larger toward its source than at its mouth. Many of the important streams that flow from the Black Hills into the Missouri are lost on their way through the plains; this is especially the case with rivers in the arid regions of New Mexico and Arizona."

The high mountains of the Main Range extend southward into New Mexico for a distance of about 100 miles, reaching the neighborhood of Santa Fé. South of this there is a semi-tropical region. "There is of necessity a wide difference in the extremes of temperature, but with the exceptions of the cold seasons of the higher lands at the north, the climate is temperate and equable. The summer days in the lower valley are sometimes quite warm, but as the dry atmosphere rapidly absorbs the perspiration of the body, it prevents the debilitating effect experienced where the air is heavier and more saturated with moisture. The nights are cool and refreshing. The winters, except in the mountains at the north, are moderate, but the difference between the northern and southern sections during this season is greater than during the summer. The snow-fall is small in amount, and seldom remains on the ground longer than a few hours. The rains fall principally during the months of July, August, and September, but their annual amount is small, seldom exceeding a few inches. When there are heavy snows in the mountains during the winter there will be good crops the following summer, the supply of water being more abundant, and the quantity of sediment carried down greater than when the snows are light."

As a general statement, it may be said that the semi-arid conditions which prevail in Colorado and the northern Territories of the Rocky Mountain region, are intensified in New Mexico. The more southern situation, and the comparative absence of high mountain ranges, forests and streams all contribute to the aridity of this region. Hon. Edmund G. Ross, governor of New Mexico, in his annual reports for 1885 and 1886 to the Secretary of the Interior, very justly urges the pressing need of constructing, in or adjacent to the mountains of that Territory, reservoirs for the storage of water. He refers to the droughts and floods with which this, in common with other parts of the West, has been afflicted, and suggests that a system of storage basins, near the head-waters of the various streams, would not only prevent destructive floods, insure supplies of water for irrigation and reclaim millions of acres now barren, but that the resulting increase in vegetable growth and conservation of moisture would also greatly modify the climatic conditions; that an increased degree of evaporation would be established, and the annual rain-fall regulated and equalized. In this connection the aid of the General Government is invoked. I most earnestly concur in the foregoing. There is urgent necessity for the systematic storage of water in most parts of the Rocky Mountain region, and especially in the southwestern Territories. Had the mountain forests been maintained the need of artificial reservoirs would not now be so great.

"The average rain-fall from 1870 to 1885, inclusive, has been as follows, at the points named, to wit:

	Inches.
Fort Bayard, in the southwest	15.30
Fort Union, in the north	16.74
Fort Wingate, in the west	15.52

"At Fort Stanton, in the southeast, the average has been about the same."

Although the principal forests of New Mexico are confined to the mountain chains, other parts of the Territory are more or less wooded. Upon the wide mesas, which form so prominent a feature of the southwest and western portions, are found scattering growths of Cedar,

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NOTE.—It is estimated that New Mexico has irrigating canals and ditches equal in extent to those of Utah, irrigation having been practiced in a rude way in this Territory long before it came into the possession of the United States. Two large irrigating canals are now projected, one on each side of the Rio Grande, capable of watering from 3,000,000 to 4,000,000 acres.

Juniper, and Piñon; while the *arroyos*, or depressions in the mesas, contain fine groves of Mesquit. In the mountain valleys, gulches and canyons, are Yellow Pine, Piñon, Dwarf Maple, and Scrub Oak. On the higher ranges, at the north, in addition to the Pines, are found the White Spruce and Red Fir. Juniper is common on the foot-hills of this section. The river valleys are lined with Cottonwood, Box-Elder, several varieties of Willow, Alder, Ash, Sycamores, Cherries, and Mulberries. On the southern plains, or wide sandy valleys, the prevailing growths are Yucca, Madroña, and Palo Verde (acacia). On mountain slopes the second growth is often Aspen. The elevated plain, which occupies the eastern portion of the Territory, has no forests, and is practically treeless. The finest timbered region in New Mexico is in the southwestern part, and includes the Magdalena, Mogollon, Sierra Diablo, and other high ranges. Large bodies of Pine, Spruce, and Fir, suitable for lumber, are found here. In the northern mountains, at the headwaters of the Rio Pecos, there is some excellent timber.

Viewing the Territory as a whole, the Yellow Pine is the most important and useful tree, and furnishes a large proportion of the native lumber.

The following is a list of the forest trees of New Mexico:

Yellow Pine (*Pinus ponderosa*, Dougl.).
White Pine (*P. reflexa* and *P. flexilis*, Engelm.).
Black Pine, or Tamarack (*P. Murrayana*, Balfour).
Pinus Chihuahuana, Engelm.
Piñon, or Nut Pine (*P. edulis*, Engelm.).
White Spruce (*Picea Engelmanni*, Engelm.).
Red, or Yellow Fir (*Pseudotsuga Douglasii*, Carr.).
White, or Balsam Fir (*Abies concolor*, Lindl. and Gordon).
Juniper (*Juniperus pachyphloea*, Torr.).
Juniper (*Juniperus occidentalis*, Hook. var *monosperma*, Engl.).
Red Cedar (*Juniperus Virginiana*, L.).
Cypress (*Cupressus Guadalupensis*, Watson).
Sycamore (*Platanus Wrightii*, Watson).
Box Elder (*Negundo aceroides*, Moench).
Dwarf Maple (*Acer glabrum*, Torr.).
Dwarf Maple (*Acer grandidentatum*, Nutt).
Ash (*Fraxinus pistaciæfolia*, Torr.).
Walnut (*Juglans rupestris*, Engelm).
Black Oak (*Quercus Emoryi*, Torr.).
Locust (*Robinia Neo-Mexicana*, Gray).
Mesquit (*Prosopis juliflora*, D. C.).
Cottonwood (*Populus monilifera*, Ait.).
Cottonwood (*P. angustifolia*, James).
Cottonwood (*P. Fremontii var. Wislizeni*, Watson).

NOTE.—Estimates of forest areas differ widely for the same region. This results from the difference in the competency and carefulness of the observers, and from the fact that there is no accepted standard of estimate. Some include in forest lands not only those tracts which are densely or mainly covered with trees, but also grazing lands on which may be found only a few scattering piñons or cedars. The estimates here given of the forest areas of New Mexico, as indeed all the estimates of forest areas embodied in this report, are designed to embrace only those which are strictly forest clad. The constant endeavor has been not to overestimate in this respect.

Aspen (*P. tremuloides*, Mich.).
Willow (*Salix flavescens*, Nutt).
Willow (*S. lasiandra*, Benth.).
Desert Willow (*Chilopsis saligna*, D. Don).
Alder (*Alnus oblongifolia*, Torr.).
Wild Cherry (*Prunus Capuli*, Cav.).
Mountain Mahogany (*Cercocarpus ledifolius*).
Mountain Mahogany (*C. parvifolius*, Nutt).
Black Thorn (*Cratægus tomentosa*, L.).
Spanish Buckeye (*Ungnadia speciosa*, Endl.).
Wild China or Soapberry (*Sapindus marginatus*, Willd).
Spanish Bayonet (*Yucca baccata*, Torr.).
Madroña (*Arbutus Xalapensis*, H. B. K.).
Palo Verde or Greenbarked Acacia (*Parkinsonia Torreyana*, Watson).
Mexican Mulberry (*Morus mycrophilla*, Buckley).

It has been estimated that the amount of native lumber used in the Territory in the year 1886 was 5,000,000 feet. About 1,000,000 feet were imported from Arizona, and used for all purposes, including finishing. Of high grade Eastern and California lumber, about 50,000 feet of each kind were consumed during that year. Some 200,000 feet of different grades were brought into southern New Mexico from northern Texas during the period named. The consumption of lumber for that year was comparatively light.

Farming and fruit-growing are carried on quite extensively in different parts of the Territory generally with the aid of irrigation. Most of the ditches, however, are small. In some of the mountain districts crops are grown without the aid of irrigation.

The Territorial law provides for the punishment of persons who shall willfully or maliciously set on fire any woods, marshes, prairies, or other grounds not their own, or who shall intentionally or by neglect permit the spread of fire from their own grounds to those of another; also, that satisfaction in damages may be recovered by parties injured by such fires.

New Mexico is subdivided into fourteen counties, the relative situation of which, upon the map, is about as follows:

San Juan. Rio Arriba. Taos. Colfax.
Bernalillo. Santa Fé. Mora.
Valencia. San Miguel.
Socorro.
Sierra. Lincoln.
Grant. Dona Ana.

BERNALILLO COUNTY.

(Area, 8,350 square miles; estimated forest area, 1,450 square miles.)

The Rio Grande River traverses the eastern part of Bernalillo County from north to south. Its principal tributaries are the Rio Galisteo on the east, and the Rio Jemez and Rio Puerco Rivers at the west. In addition to the above, there are numerous springs, and a few small streams of more or less permanence. The Rio Grande is the most important valley, and includes a large area of agricultural land. To the westward of this valley the county is rolling and broken by hills and canyons. It has grass lands and some timber, and is well adapted for grazing purposes. The Sandia Mountains occupy the eastern and the Jemez Mountains the central portions of the county.

Upon the mountains named above are situated most of the forests. About one-fourth of the forest area has good timber, and as much more has a promising young growth. Open forests of Yellow and White Pine and Red Cedar extend from the northeastern corner of the county westward to the Jemez River. The principal species of trees, in addition to those named above, are Scrub Oak and Piñon, the latter predominating.

But little change, if any, has been observed in the volume of water in the streams of this county; the flow is more intermittent than in former years, and floods have become more frequent.

COLFAX COUNTY.

(Area, 7,000 square miles; estimated forest area, 1,275 square miles.)

This county is situated in the extreme northeastern corner of the Territory. It is bordered on the west by the Main Rocky Mountain range, and its surface, as a whole, is greatly varied. Mountains, single and in groups, hills, buttes, rolling lands, mesas, and valleys are embraced within its limits. Numerous streams, the most important of which are the Cimarron and Canadian Rivers, traverse the region. This, with the fine growth of grass, makes it one of the best grazing districts of the west.

The forest lands are situated principally in the western part of the county and constitute about one-fifth of the entire area. Nearly 10 per cent. of the timber is Pine and Spruce of medium size. The remainder is mostly Aspen, Scrub-Oak, Piñon, and Dwarf Cedar. Cottonwood grows along the streams.

There is less water in the streams in summer than there was fifteen years ago. Floods and droughts have become more frequent.

DONA ANA COUNTY.

(Area, 10,260 square miles; estimated forest area, 75 square miles.)

Dona Ana is the central county of the southern tier bordering on Texas and Mexico. It is, in general terms, a strip of table land about

4,000 feet above the sea level, from which rise a number of mountain ranges. These ranges are from 20 to 50 miles long, and seldom exceed 10 miles in width. Between them are great plains, from 20 to 80 miles wide, treeless and almost waterless, but generally covered with grass and affording pasturage for stock. The Rio Grande del Norte flows through the center of this region, forming a rich alluvial valley about 5 miles in width and sunken some 200 feet below the surrounding plains. It includes the famed "Mesilla Valley," a district noted for its fine fruits and immense crops of cereals. Between the valley of the Rio Grande and the Organ and San Andres Mountains at the eastward is a desolate region known as the "*Journanda del Muerto*" (Journey of Death). With the exception of the valley of the Rio Grande, which includes some 300 square miles of alluvial land that may be irrigated, but a small portion of the county is adapted to the production of crops.

There is but little timber in this county, and it is mostly confined to the higher portions of the Organ and Sacramento Mountains. Pine, Fir, Cedar, and Juniper are the principal species growing in the mountains, and forming forests. The first two are used to a limited extent in the manufacture of lumber. Piñon, Oak, Ash, Mesquit, Cottonwood, and Willow are also native to this region. Oak and Ash are used in wagon and carriage work.

When the forests are destroyed, there is absolutely no chance for their natural reproduction, and the denuded tracts become barren wastes.

GRANT COUNTY.

(Area, 10,090 square miles; estimated forest area, 800 square miles.)

Grant county is in the southwestern corner of the Territory, bordering on Mexico. The northern portion is mountainous, and includes the sources of the principal streams, the Rio Mimbres and Gila River. The southern half of the county consists mainly of plain and mesas, and has an average or mean elevation of about 5,000 feet. The great plateau of the Sierra Madre extends into the southeastern portion of the county. A little farming is carried on in the large valleys, but stock-raising and mining are the chief industries.

The largest bodies of timber are situated in the Black Range, Mimbres, Pinos Altos, and other mountains in the northern part of the county. The Florida Mountains upon the eastern border, and the Hades and Peloncillo Mountains in the southwestern portion, are also wooded to some extent. About one-tenth of the forest area is well stocked. Pine and Juniper are the predominant species of forest trees and attain a good size. A scattering growth of Scrub Oak is found on the mesas and Cottonwood fringes the streams in some places. The forests proper are rarely dense; there is but little undergrowth, and the loss incurred from forest fires is inconsiderable. In fact, fires in this section are more destructive to the stock ranges than they are to timber.

The demand for lumber causes the consumption of the Pine timber as fast as it can be reached. Much of the best Pine is situated at points in the mountains not now accessible, and for the present it is likely to be spared. After the forests have been destroyed their reproduction can hardly be hoped for; the region is too arid to favor a new coniferous growth.

LINCOLN COUNTY.

(Area, 24,450 square miles; estimated forest area, 920 square miles.)

This county is situated in the southeast corner of New Mexico. Along its western border are the Sierra Blanca, Sacramento, Guadalupe, and other mountain ranges; the central and eastern portions extend into the plains region. The Rio Pecos River flows through the entire county from north to south, and midway in its course is joined by its main affluent, the Rio Honda River, which enters it from the west. That part of the county east of the Rio Pecos is very scantily watered, a few springs and wells being the only source of supply. Stock-raising is the chief industry, for which the county is well adapted. A large body of tillable land lies along the valley of the Pecos for a distance of about 200 miles, and along the tributaries of the river for a distance of some 300 miles.

The forests of the county are confined mostly to the mountains of the western portion. About one-fourth of the forest area includes good timber; the remainder has a small growth suitable only for fencing and fuel. Forest fires have, as yet, done but little damage. Pine, Spruce, Piñon, and Cedar constitute the bulk of the forests. The first two are used in the manufacture of lumber. Spruce is found at the greater elevations; it grows large and often forms dense forests. Piñon, "Scrub Pine," and Cedar are the most prevalent trees. Other trees native to this county are Oak, Yucca, and Madroña.

Settlers who have taken timber-culture claims, generally plant Cottonwood, cultivating them in all cases with the aid of irrigation.

MORA COUNTY.

(Area, 3,830 square miles; estimated forest area, 720 square miles.)

The altitude of this county varies from 4,000 feet in the extreme eastern portion to 7,000 feet at the base of the Rocky Mountain range in the west, and some of the high peaks attain an elevation of 11,000 to 12,500 feet. About one-fourth of the surface of the county in the western part is mountainous; the remaining three-fourths extends into the Plains Region, and is an open rolling country, varied to some extent by hills and buttes. The Canadian River, passing from north to south through the central portion, is the principal stream. A number of creeks and arroyos water other portions.

The heaviest bodies of timber, consisting of Yellow and White Pine and Spruce, are found in the mountains. Here, also, are large tracts covered with Aspen. The trees of this species grow very straight, are from 10 to 40 feet in height, and are much used for fence poles. Upon the lower slopes and foot-hills the predominating species are Piñon, Cedar, and Scrub Oak; the latter sometimes growing to a height of 30 feet. The central portion of the county has scattered groves of Piñon and Cedar, with patches of Scrub Oak. The bluffs overhanging the streams are covered, to a limited extent, with Piñon, Cedar, Scrub Oak, Mesquit, and a few Pines. Cotton-wood, Box Elder, Hackberry, Mulberry, Wild Plum, and Wild Cherry line many of the water courses. The streams of the eastern portion are nearly bare of trees, the groves that once existed there having been destroyed by the early settlers.

RIO ARRIBA COUNTY.

(Area, 7,500 square miles; estimated forest area, 175 square miles.)

The eastern and central portions of Rio Arriba County are mountainous and well watered. The western portion is occupied by high mesas and plains, which here constitute the Continental Divide. The Rio Chama is the principal river traversing the county for any considerable distance. This and a few smaller streams discharge their waters into the Rio Grande, which flows through the southeastern part of the county. The valleys of the streams are fertile, producing fine crops of grain and vegetables, and yielding different kinds of fruit.

The forests, found mainly in the mountainous districts, consist chiefly of Yellow and Black Pine, with some Spruce at the higher altitudes. The timber is not dense, nor are the trees of large size. Cedar, Piñon, Scrub-Oak, Cottonwood, Willow, and Wild Cherry are also native to this county.

About one-fourth of the forest area has been made waste by fire, and as much more is brush of promising growth. After the destruction of the forests from any cause their renewal is extremely difficult.

Floods and droughts are more frequent than in former years.

SAN JUAN COUNTY.

(Area, 7,200 square miles; estimated forest area, 250 square miles).

This county has an elevation above sea-level of 7,000 feet. The San Juan Mountains border it at the north and the Chusca Mountains at the west. In the central and eastern portions are wide plains and mesas. The San Juan and Chusca Rivers and their affluents constitute the water system of the county.

The Chusca Mountains are fairly well timbered, Yellow and Black Pine being the predominant forest trees. A scattering growth of Cedar, Piñon and Scrub Oak is found on the foot-hills and mesas. Cottonwood, Willow, and Wild Cherry grow along the streams.

SAN MIGUEL COUNTY.

(Area, 11,630 square miles; estimated forest area, 1,300 square miles.)

The northwestern portion of this county, including about one-sixth of its area, is mountainous; the remaining part is an open, rolling country, embracing wide plains and extensive mesas. The surface slopes from the western boundary of the county to the Texas State line on the east, the average or mean altitude being about 5,000 feet above sea-level. The Canadian and Rio Pecos Rivers and their tributaries, which have their sources in the mountains at the north and west, constitute the drainage system.

The most important forests, consisting of Pine and Spruce timber, are situated in the mountains. It is estimated that about one-half of the forest area is well stocked, that most of the remainder is brush of promising growth, and that a small part has been made waste by fire. Scattering groves of Piñon, Cedar, and Scrub Oak are found on the foot-hills and mesas. Cottonwood grows along some of the water-courses.

No changes have been observed in the flow and volume of water in the streams.

SANTA FÉ COUNTY.

(Area, 2,490 square miles; estimated forest area, 1,375 square miles.)

Santa Fé County is situated in the northern-central part of the Territory. It is bordered at the northeast by the elevated crests of the Rocky Mountain range, which here reaches its southern limit. The surface of the county is finely diversified. It is a region of mountains, valleys, mesas, undulating plains, and swift running streams. The altitude varies from 5,500 feet on the mesas in the southern portion of the county, to 7,044 feet at the city of Santa Fé, and to 13,000 feet on Mount Baldy, of the Santa Fé range. The area of the county is quite equally divided between agricultural, fruit, grazing, and timber lands. The temperate climate, fine scenery, and other natural advantages, contribute to render this region most attractive and desirable for residence.

The forest lands are situated mostly in the eastern part of the county. There is a narrow strip of timber at the south called "The Placers," extending from the Placers to the east line of the county, and also a small wooded tract in the southwestern corner. About 30 per cent. of the forest area includes good timber; 20 per cent. is brush of promising growth; a portion has been burned over, and the remainder is an open growth of Piñon, Cedar, and Scrub Oak. Yellow Pine and Spruce are the predominating species in the mountains in the northeastern part of the county; in the more open country at the south and west, Piñon, Cedar, and Oak are the prevailing kinds. Cottonwood and Willow border many of the streams.

SIERRA COUNTY.

(Area, 3,200 square miles; estimated forest area, 250 square miles.)

This county is situated in southwestern New Mexico. Its surface includes mountains, valleys, and mesas. The Rio Grande River, its most important stream, traverses the east-central part from north to south, and its broad valley embraces a large section of arable land. The county is well watered, and the table lands of the western portion afford good pasturage.

The forests are mainly situated in the Black Range at the northwest. Pine and Fir are the predominant trees at the higher elevations; Juniper and Oak are found on the foot-hills and mesas, and a growth of Maple and Walnut borders some of the streams.

When the forests have been destroyed they are rarely, if ever, reproduced. The second growth is usually Scrub Oak.

The large streams are not as continuous in their flow as they were before the timber in the mountains was cut off. There are more floods and longer periods of drought. Many of the small streams have wholly failed.

SOCORRO COUNTY.

(Area, 16,500 square miles; estimated forest area, 2,050 square miles.)

This county has several classes of lands—the agricultural, which are found on the Rio Grande and other streams traversing the county; the uplands or mesas, especially adapted to grazing; and the mountain ranges, upon which the forests are mainly situated. In addition to the above, the San Augustine Plains, centrally situated, cover an estimated area of 2,000 square miles, and are wholly destitute of trees. In the eastern part of the county is a wide extent of desert, embracing barren plains, lava beds, treeless mountain ranges, and "Mal pais."

From one-third to one-half of the county is sparsely covered with forests, if all classes of growth are considered. Along the northern slopes of the Piñon and Datil Mountains, upon the Magdalena Mountains, the San Francisco and Mogollon Ranges, and on the higher portions of the Black Range are forests composed mainly of the Yellow and White Pine and Red, or Douglas, Fir. Extensive tracts of large Pines are rare, although there are a few in the western part of the county. About four-fifths of the entire forest area consists of a small growth of Pine, Cedar, Juniper, and Oak. Burned tracts of limited extent are common, but they are usually confined to the scrub growths. Aspen covers large areas in the mountains. Other species native to the region are Mountain Mahogany, several varieties of Oak, Walnut, Mesquit, Box-elder, Water Maple, Cottonwood, Willow, and Wild Cherry.

After the destruction of the forests, from any cause, there is hardly any chance for their renewal. Tracts burned over ten years ago are still barren.

TAOS COUNTY.

(Area, 2,300 square miles; estimated forest area, 900 square miles.)

This county is centrally situated upon the northern line of New Mexico. Its eastern boundary is the Main Rocky Mountain range. The Rio Grande River runs through the central part of the county, from north to south. Numerous small streams flow from the mountains at the eastward and unite with the Rio Grande. This district is the best watered of any in the Territory. The western portion of the county is more arid than the rest, but is well fitted for grazing purposes.

The forest land is situated mostly in the eastern and southern parts of the county, excepting a narrow strip along the western side. About five-eighths of the forest area is fully stocked—good for timber; the remainder consists of young growth and tracts made waste by burning. In the mountains are quite heavy bodies of Yellow, White, and Black Pine, Spruce, and Fir. Aspen also covers large tracts which have been denuded of the original species. At lower altitudes are Scrub Oak, Piñon, and Cedar, some of the latter being quite large. Cottonwood (*Populus monilifera* and *P. angustifolia*) borders many of the streams.

By a proper system of irrigation, at least one-half of the entire area of the county could be brought under cultivation. At the present time, only a very small proportion of the land is cultivated.

VALENCIA COUNTY.

(Area, 7,700 square miles; estimated forest area, 960 square miles.)

This county, which is situated in central New Mexico, extends from the western border three-fourths of the distance across the Territory. Near the center it is divided by the Rio Grande River, and at a few miles west of that point it is again intersected by the Rio Puerco River. These two streams, and the Zuñi River in the west, are the principal water-courses. Portions of the county are very broken and mountainous. The Zuñi and San Matéo Mountains at the northwest, and the Manzano Mountains east of the Rio Grande, are the most important ranges. Although farming and fruit growing are prosecuted to some extent along the valleys of the streams, the region, as a whole, is better suited for grazing than for other branches of husbandry.

Extensive forests of Yellow Pine exist in the mountains, both in the western part of the county and in the Manzano Range to the eastward. In the last named district the estimated forest area is 280 square miles, three-fourths of which bears good timber. Saw logs obtained here are from 2 to 4 feet in diameter. At lower altitudes Piñon, Cedar, and White and Scrub Oak abound.

UTAH.

As stated in the introduction, a full canvass of this Territory could not be made on account of deficiency of appropriation, and only the following résumé, therefore, is given :

The Territory of Utah comprises 84,476 square miles within the thirty-seventh and forty-second degrees of latitude and the one hundred and ninth and one hundred and fourteenth degrees of longitude, a parallelogram 300 by 325 miles in extent, of which the northeast corner is cut out, however, by the southwestern boundary of Wyoming entering with a right angle; the western line of about 70, the southern of over 100 miles. The country is rugged and broken and is separated into two unequal sections by the Wahsatch Mountains, which cross it from northeast to southwest, while the Uintah Mountains in the northeast have an east and west extension. In the southeast are extensive plateaus, and in the west a series of disconnected ridges, generally extending from north to south.

East of the Wahsatch the drainage is mostly by the streams which form the Colorado, of which the principal are the Grand and Green Rivers, and their tributaries, the White, Uintah, and San Rafael. These rivers are mostly rapid, not navigable, and flow through rocky canyons, whose walls in some places rise 2,000 feet above the streams. The rivers of the western half have no outlet to the ocean, but terminate in the various lakes. Of these the largest is the Great Salt Lake in the northwest, which is 75 miles long and about 130 broad. It is shallow, contains several islands, and receives by means of the river Jordan the waters of Utah Lake, 26 miles to the southeast. Several streams flow into it. It has no outlet and its waters are exceedingly saline, containing about 22 per cent. of salt and having a specific gravity of 1.17. Utah Lake is a beautiful sheet of fresh water, having an area of about 130 square miles, and closely hemmed in by mountains. The Sevier River, rising in the southern part of the Territory, flows north for 150 miles, receiving the San Pete and other smaller streams, then bends southwest and forms Sevier Lake, nearly 100 miles southwest of Great Salt Lake, and about equal in size to Utah Lake. Only that portion of Utah which can be artificially watered is really arable, though lands not irrigable are being more and more brought under cultivation. Of that part of the Territory lying east of the Wahsatch Mountains little use has yet been made. It is mountainous; its valleys are about a mile above the sea-level, and it consists chiefly of grazing and coal lands. The settled parts of the Territory lie along the western base of the Wahsatch Mountains, between them and Salt Lake and Utah Lake, in Cache, San Pete, and other valleys, wherever streams are so situated as to render irrigation practicable. In the northern part of the Territory the Wahsatch is high, there is a great accumulation of snow in winter, and the streams are large and numerous. In the southern part, though the range is nearly as high, the atmosphere is warmer and there is little snow, the streams are smaller and fewer in number, and there is less land capable of cultivation. The isolated ranges in the Great Basin give rise to no streams of importance, and the valleys are mostly of a desert character. The possible amount of farming lands in Utah may safely be put at 3,000,000 acres (probably an underestimate).

The climate of Utah varies with its differing altitudes and exposures. In the lower valleys it is agreeable and salubrious. The air is dry, elastic, transparent, and bracing. The Great Salt Lake exercises a mollifying influence on the extremes of temperatures, while the dry and absorbent character of the atmosphere relieves the oppression felt in humid climates at high temperatures. The average humidity in winter is more than twice as great as in summer. For the year the rain-fall averages 17.3 inches, 40 per cent. of which is in the spring, 9 in the summer, 25 in the fall, and 26 in the winter. The meteorological registers do not show an increased moisture in the climate; but Rush Lake covers what was a meadow twenty years ago, and the water of Great Salt Lake is 10 feet higher than it was in 1863. There has been little gain, however, during the last ten years. It is a peculiarity of climate in Utah, as in some other portions of the arid region, that there is a preponderance of rain-fall in the spring, when it is most needed.

With respect to timber Utah is much like Colorado, combining a treeless plain with timbered mountain ridges on one side of the Territory. The valleys or plains are destitute of forest growth, and in early times willow brush was resorted to for fencing, adobe bricks for building, and sage brush for fuel. The valuable timber is found in the canyons and coves, the mountain sides having mostly only a scrubby growth of comparatively little account. The Uintah Range, the eastern flank of the Wahsatch, with San Pete and San Pitch ranges, are generally more or less wooded with conifers. The western flank of the Wahsatch Mountains has been nearly stripped of what good timber it may have had, and from that range westward to Nevada it may be said that the country is destitute of timber. In the southern and extreme southeastern portions of the Territory there is a thin covering of forests on the mountain ranges, but of an inferior character. Of the timber of Utah it may be said that the best trees furnish lumber of an inferior quality only. The forests are composed chiefly of Red Cedar, Red or Douglas Fir, Spruce, with occasional Bull Pine (*P. ponderosa*), and White Pine (*Pinus flexilis*). More than half of the forest growth of the Wahsatch Range is composed of this last Pine, of inferior quality. On the Oquirrh the trees are chiefly Douglas Fir. A scrubby growth of Red Cedar and here and there Piñon Pine cover the larger part of the mountain sides in the south and west. They are of little value except for posts, ties, and fuel. For lumber of good quality Utah is almost entirely dependent upon supplies from the Pacific slope and Eastern States, yet the total cut of native timber in Summit and Wahsatch Counties has been estimated at not less than 2,000,000 feet of lumber, 300,000 cubic feet of round mine timber, and 12,000 cords of fuel and fencing, and this is claimed to represent only 20 per cent. of the cut in the Territory.

On the whole, Utah ranks very low among our States and Territories in respect to woodlands, having only 7.6 per cent. of her area which can be called forest. One who had occasion to make a special investigation of the resources of this Territory, and supposed to be a competent observer, says: "It may be stated that Utah seemed very generally lacking in serviceable material for fencing or building. The country settled for thirty years has drawn upon the near supply of standing timber, so that now lumber is obtained by great exertion and expense in most of the valley settlements. The labor and expense of fencing caused Brigham Young to enact the no-fence law, which enabled the destitute settlers to break ground, irrigate, and raise grain without the provision of any barrier against stock inroads, the cattleman being held responsible for the damages of his herd. This law in itself is a commentary on the scarcity of timber in Utah."

Iron ores occur all over the Territory in great variety. The most important deposits known are in Iron County, about 300 miles south of Salt Lake. The ore belt is 15 or 20 miles long and 3 or 4 miles wide. The ore is magnetite and hematite. Gold, silver, copper, lead, and other metals also abound in the Territory, and the production of the mines is annually increasing. The reported value of the gold, silver, copper, and lead product for the year 1886 is $7,631,729.

An inexhaustible supply of salt is obtained from the Great Salt Lake, which is constantly fed by salt springs, which abound in the northern part of the Territory and discharge into the lake.

Stock raising is becoming an important industry in Utah. Much land unfitted for agriculture is adapted for grazing purposes, and the mountain slopes are covered with nutritious grasses. Cache Valley, the valley of Green River, and other sheltered situations, offer superior advantages for sheep husbandry.

If Utah is deficient in timber it abounds in building stones of good quality and great variety and very accessible. Among the best known are the granite, from the mouth of Little Cottonwood Canyon, the red sandstone near Salt Lake City, and the secondary sandstone or oolite of San Pete County. At Logan there is an easily quarried limestone. Marbles of various colors and susceptible of good polish, are found at many points, and at Antelope Island is found, in unlimited quantity, a green and purple slate, which for roofing and some other purposes is said to be superior to the eastern slates.

Without subscribing in all respects to the views expressed in the following communication, kindly forwarded by Mr. O. J. Hollister, of Salt Lake City, it is here given in full, as showing in general the manner in which forestry interests are spoken of:

"In the ordinary use of the word, I should say that 'forestry' has no meaning in Utah. There is on the acclivities of some of the mountains a fair growth of coniferous trees, but where these were accessible through canyons the saw timber has mostly been cut out and used. Railroads have stripped other accessible parts of the ranges for ties, and in the mining canyons and districts all the timber has been used in the mines and for fuel—that is, all that is within reach. Now they are obliged to reach out farther, many of them being forced to use the railways to get what they require. No fires ever run in these Utah woods.*

"The natives (Utes) lived more in the valleys than in the mountains. The white settlements along the mountain streams of course protect the wild lands in their vicinity from fires. There is no object in preserving these patches of trees as a protection to the streams, either. The snow-fall on the mountains is very heavy, and does not melt and run off in the streams until June and July. The ground in the mountains is thus kept wet and heavy until the snow begins to fall again. There is little if any waste of timber. Of course all belongs to the Government, save where the miners may have patented the lands as mines. Most of the timber of Utah was originally confined to the Wahsatch and the Oquirrh ranges. The canyons of many streams admitted the lumberers and saw-mills to the former, and to a less extent, the range being far slighter, to the latter.

"In the southern part of the Territory, the varieties—Cedar and Piñon Pine—are more scattered and scrubby. The more valuable varieties of the Wahsatch and Oquirrh are the Red Pine, Black Balsam, and the White Pine. More than half of the finest growth of the Wahsatch is said to be of the white or inferior pine. The Red Pine and Black Balsam make a railroad tie that lasts ten years. On the Oquirrh the trees are chiefly Red Pine. The Scrub Cedar and Piñon Pine are of little value except for posts, ties, and fuel. The larger trees of the better varieties furnish a lumber not technically clear, but the knots are held so fast that they are no great detriment, and the lumber is practically clear. For many years a great part of the lumber used in the Territory has been imported from Nevada or Wyoming. Ordinary rough building and fencing lumber is worth about $25 per thousand; flooring and finishing, perhaps $45. In the early settlement of Utah willow brush and even sage brush were used for fencing. Now the use of barbed wire, strung upon cedar posts, is almost universal. Very little wood is used for fuel, even the mines, as well as the railroads, using coal, of which there is a great abundance in the Territory, and also in Wyoming, near the eastern line of Utah. The native growth of forest exercises the mind of the people not at all. What trees they have they have planted, watered, and tilled. The settlements in the lower valleys are collections of orchards, the streets lined with shade trees. After being once well started, and becoming of some size, they seem to do petty well even without water. Very little attention has been given as yet to starting plantations of trees other than for purposes of shade. It is doubtful, perhaps, if the valleys are very well adapted to the growth of trees; doubtful if they would not come to maturity and begin to decay before reaching any great size or age. One gets that impression from observing the Locusts, the Cottonwoods, the Box Elders, and the Poplars grown in the towns for shade. But possibly they do not have as fair a show for thrifty growth and long life as they would in more secluded places, where the earth would not be tramped upon their roots, and their bodies constantly marred and bruised. Undoubtedly more and more attention will be given in Utah to the raising of forest trees as the Territory becomes more thickly settled. But there is not enough land that can be spared for such a use to ever make it of much importance."

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*The census of 1880 reports 42,865 acres of woodland in Utah destroyed by fire during the census year.

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and fu	annual rain-fall ..	But little in this county; amount of rain-fall or precipitation determined by the condensation as caused by the mountain ranges.
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FOREST FLORA OF THE ROCKY MOUNTAIN REGION.

By George B. Sudworth,
Forestry Division.

The following chapter is intended to embody an account of all the strictly woody plants occurring in the Rocky Mountain region. These have been divided into arborescent and non-arborescent species. But the dividing line must necessarily be an arbitrary one, and undoubtedly many exceptions could be taken to the species thus termed arborescent, a large number being little more than shrubs as commonly found, yet the controlling feature has been rather the capabilities of each species under specially favorable conditions, such as may occur more or less in the region under consideration.

Besides the range of each species within the Rocky Mountain region, the general distribution of those species not particularly confined to these limits has been placed in parentheses and given mostly in general terms. The descriptions of the species do not pretend to be technical (or even complete), the attempt here made being rather to avoid, as far as possible, the use of such botanical terms as will not be readily understood by the laymen, and to note such characters as are most apt to be seen by the casual observer; hence the lack of attention to floral organs as studied by the professional botanist. An artificial key to the genera and species has been prepared on the same basis, and it is hoped will lend some aid to the laymen in studying the flora. A fuller description has been given only for the arborescent species.

The conifers have been somewhat arbitrarily arranged and placed first, as in this region at least they are without doubt forestally of greatest importance; otherwise the order of arrangement followed is that of Bentham and Hooker's Genera Plantarum. The nomenclature is that given by Dr. Gray in his Synoptical Flora of North America, supplemented by that adopted by Dr. George Englemann, Professors Sereno Watson, M. S. Bebb, and C. S. Sargent. As regards the common names used, such confusion exists that it is difficult to determine which names are most used and most appropriate; for in many sections the same name is applied to different species. But it is highly desirable for practical purposes that a uniformity in nomenclature should be maintained; and it is with this object in view that the selection of the first name given has been made.

Information has been derived from an examination of herbarium and other specimens, as well as from a free use of a large number of forestal and botanical publications; among them Gray's Manual, Watson's Botany of California, Prof. C. S. Sargent's Forests of North America, Coulter's Manual of Rocky Mountain Botany, together with various Government reports and current botanical and forest literature. Information has also been derived from the personal observations and correspondence of Col. E. T. Ensign.

ARTIFICIAL KEY TO GENERA AND SPECIES.

I. Leaves without a true stem:	
Needle-shaped or scale-like	CONIFERS.
Sword-shaped, very long, thick, attached to an unbranched trunk	YUCCAS.
II. Leaves with a true stem and a more or less broad blade	BROAD-LEAVED TREES.
III. Leaves none (anomalous)	49

CONIFERS.

Leaves in clusters:	
2, 3 (not regularly 4), or 5, with a delicate scaly sheath at the base: PINES:	
Leaves 2 in a sheath:	
1 to 2 inches long; cones with blunt scales	5
1 to 3 (mostly 2) inches long; cones with prickle-pointed scales	9
Leaves 3 (sometimes 2) in a sheath:	
2½ to 3¼ inches long; cones with delicate prickles	8
3 to 6 inches long; cones with strong prickles	7
Leaves 5 in a sheath:	
1 to 1¼ inches long; cones with delicate prickles	6
1¼ to 2½ inches long; cones with blunt scales	3
1½ to 2 (exceptionally 2½ to 3) inches long	2
2¾ to 4 inches long (often 4 in a sheath); seeds large, wingless	4
3 to 4 inches long; seeds small, winged	1
More than 5, proceeding from a bud: LARCHES:	
14 to 20 leaves in a cluster	20
40 to 50 leaves in a cluster	21
Leaves single:	
Bristling all around the branches; more or less 4-sided and pointed: SPRUCES:	
Leaves very stiff, stout, and acutely pointed	12
Leaves moderately stiff, rather slender, awl-pointed:	
Cones with margin of scales entire	10
Cones with margin of scales indented	11
Comb-like, or 2-ranked in arrangement on the branches, flat, blunt, notched, or pointed:	
Leaves rather thin, on slender branches; cones hanging, scales persistent: HEMLOCKS, etc.:	
With 3-pointed bracts protruding from under the scales	19
With no bracts protruding from under the scales:	
Cones ½ to ¾ of an inch long, downy	17
Cones 2 to 3 inches long, not downy	18

Leaves single—Continued.
Leaves rather thick and stiff, on stout branches; cones erect, scales deciduous: Firs:
With a delicately-pointed bract attached to the back and extending beyond the end of each scale................ 13
With bracts not extending beyond the ends of the scales:
Cones cylindrical, slender (2 to over 5 inches long); leaves 1 to 1½ inches long, glossy, and with white lines on underside................................ 15
Cones broadly ovate stout (2¾ to 5 inches long); leaves 1 to 3 inches long, pale green 16
Cones narrowly ovate (2 to 3 inches long):
Leaves broad, thick, dense, acutely pointed, and attached by a broad base.. 14
Scattered (but somewhat 2-ranked) on the branches, thin, very concave on the underside; with a sharp ridge or keel on the upper side, and tapering suddenly to a short needle-point: Yew 27

Leaves scale-like, 2 opposite, overlapping (sometimes 3 in a whorl) on the branchlets:
Leaves (scales) blunt or only slightly acute; fruit a cone; heart-wood chiefly brownish: Cedars, etc.:
Forming rather long flat branchlets; cones ovate, made up of a few loose scales.. 22
Forming short 4-angled branchlets; cones ball-like, made up of a few scales, each with a hooked protuberance..... 23
Leaves (scales) needle-pointed, or at least sharp-pointed; fruit a berry, or nut-like; heart-wood chiefly reddish: Junipers:
Forming 4-angled branchlets:
Foliage whitish; fruit large, ½ an inch in diameter.......................... 24
Foliage whitish, but with smaller fruit, ¼ of an inch in diameter........ 25
Foliage glossy green (or tawny in winter); fruit less than ¼ of an inch in diameter, with scale-like points........... 26

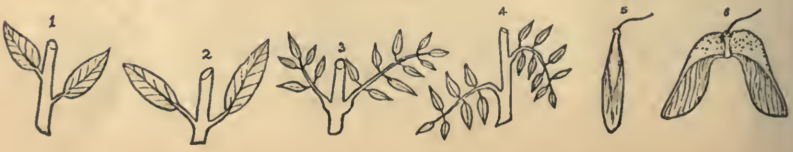
BROAD-LEAVED TREES.

Leaves simple; *i. e.*, the blade of one piece and not more modified than by lobes or teeth.

A.—Leaves set *alternately*[1] on the branches.
Branches armed:
a. With true thorns; fruit apple-like (not in size): Hawthorns:
Leaves smooth, or with few hairs only on the veins; fruit blackish 53
Or with a few hairs generally distributed over the upper surface; fruit black-purple.................................. 54
Leaves downy (sometimes smooth) above; fruit red-orange 55
b. With thorn-like branchlets; fruit berry-like or a plum:
Leaves small, ¼ to ¾ of an inch long; fruit berry-like, with scanty flesh, with a beak: Buckthorn.................. 29
Leaves much larger and longer; fruit a plum, fleshy, without a beak: Plums:
Leaves 1½ to 2 inches long.. 43
Leaves 2 to 3 inches long 42

Leaves simple, etc.—Continued.

- **Branches unarmed:**
  - *Leaves evergreen—thickish, leathery;* densely woolly or minutely downy on the under surface:
    - *a.* Margin more or less indented or sometimes entire:
      - Fruit an acorn:
        - Leaves 1 to 2 inches long 69
        - Leaves 2 to 3½ inches long 72
      - Fruit a tailed seed; leaves ¼ to 1½ inches long 51
    - *b.* Margin entire and rolled back; fruit a tailed seed 50
  - *Leaves deciduous, thin, not leathery:*
    - Margin entire; leaves very narrow, less than one-quarter of an inch wide:
      - Fruit a long (6 to 12 inches) pod 61
    - Margin variously indented, but sometimes entire, or nearly so; leaves more than one-quarter of an inch wide:
      - *a. With fine* (not prickle or bristle pointed) *teeth:*
        - Bark bitter; fruit (seed) borne in deciduous catkins, and when mature, cottony:
          - Leaves broad, triangle-shaped, or ovate (in 84); branches often angled; buds resinous: POPLARS:
            - Triangle-shaped:
              - Smooth on both sides ...... 82(86)
              - White-downy on the under surface 83
            - Ovate (exceptionally narrow, lance-shaped); smooth both sides. 84
          - Leaves narrow, lance shaped; branches round; buds not resinous: WILLOWS:
            - Less than ½ an inch wide, mostly ⅙ to ¼ of an inch 80
            - More than ½ an inch wide:
              - Pale or whitish on the under surface:
                - Leaf-stems with glands at the base of the blade 79
                - Leaf-stems without glands 78
              - Brownish downy on the under surface 81
        - Bark not bitter:
          - Separating (on trunk) into thin papery layers or sheets; seeds in a deciduous scaly catkin and with wings: BIRCHES:
          - *Coppery-yellow;* leaves 1 to 1½ inches long 74
          - *Chalky-white;* leaves 2 to 3½ inches long 73
          - Not separating into layers or sheets; fruit fleshy, or a winged seed in a persistent catkin:
          - *Leaves unequal sided* (unsymmetrical), mostly entire, but occasionally with small teeth:
            - Very rough on the upper surface; fruit cherry-like, dry, sweet 63
            - Smooth above, hairy on under side; fruit a flat winged seed—samara; belongs under "coarse teeth" 62
          - *Leaves equal-sided* (symmetrical) and always toothed on the margin:
            - Rough; freshly-wounded bark exuding a milky juice 64



Leaves simple, etc.—Continued.

- Smooth; bark without milky juice:
  - *Fruit fleshy*, or at least berry-like:
    - 1-seeded (a stone), globular: Cherries:
      - With mostly rounded teeth on the margin of leaf..... 45
      - With sharp teeth on the margin of the leaf:
        - Dull green on upper surface of leaf; commonly downy below; teeth straight................ 47
        - Shiny green on upper surface; not downy below; teeth more or less incurved:
          - Green on the under surface...................... 44
          - Pale on the under surface:
            - Margin often with teeth of two sizes........... 48
            - Margin with teeth of only one size............ 46
    - 3-seeded, pear-shaped: Buckthorns:
      - Margin of leaf wavy, sometimes with *very* small teeth, or nearly entire.............................. 30
      - Margin of leaf always toothed and somewhat downy on the under surface 31
  - *Fruit not fleshy* nor berry-like—a catkin with persistent woody scales: Alders:
    - Base of the leaf wedge-shaped...................... 75
    - Base of the leaf rounded or heart-shaped.............. 77
- *b. With coarse* (not bristle or prickle pointed) *teeth:*
  - Leaves equal-sided; teeth of one size or of two sizes and glandular-pointed:
    - Broadly triangle-shaped, not glandular-toothed; bark bitter: Poplars:
      - Teeth hairy, close, and much incurved..................... 85
      - Teeth not hairy, rather distant, and but slightly incurved.... 86
    - Ovate or lance-shaped, glandular-toothed; bark not bitter: Alder 76
  - Leaves unequal-sided; teeth of two sizes, but not glandular-pointed: Elm........................... 62
- *c. With deeply-cut blunt or pointed lobes,* distant-undulate, prickle or bristle pointed teeth:
  - Circular in outline, with 3 to 7 (mostly 5) deep, sharp-pointed lobes; fruit a "ball": Sycamore 65
  - Ovate, etc., in outline; fruit an acorn: Oaks:
    - Leaves very large, 4 to 10 inches in length, with 3 to 6 pairs of deep blunt lobes 68
    - Leaves smaller, mostly less than 3 inches long:
      - With bristle-pointed, deeply-cut teeth (occasionally with 3 to 5 somewhat equal blunt lobes) 67
      - With prickle-pointed shallow teeth (sometimes with wavy, but not lobed margin):
        - Halberd-shaped; mature leaves usually glossy green on both sides 71
        - Ovate or elliptic; mature leaves usually downy on the under side 70

B.—Leaves set *opposite*[2] on the branches:

- Margin deeply cut with 3-pointed lobes; fruit (seed) a 2-winged key[6]: Maples:
  - Lobes mostly entire, or only occasionally with coarse teeth............ 35
  - Lobes always with rather fine sharp teeth 34
- Margin entire, or only slightly indented with shallow, rounded teeth; fruit a 1-seeded key[5]: Ash...................... 57

Leaves compound: *ie.,* composed of leaflets which are arranged in pairs (opposite) along a leaf-stem (pinnately compound) as in peas and beans; or, a number of leaflets radiating from the end of the leaf-stem (digitate or palmately compound), as in the Horse Chestnut.

- A.—Leaves (not leaflets) set *alternately*[4] on the branches.
  - Branches armed:
    - *With pairs of straight thorns;* leaflets equal-sided (symmetrical):
      - Branchlets and leaf-stems thickly set with bristle-like hairs with glands at the tips 37
      - Branchlets and leaf-stems not glandular-hairy:
        - Thorns pearly white; fruit-pods closely coiled in a spiral 40
        - Thorns yellowish; fruit-pods flattened (not coiled) 39
    - *With short hooked prickles;* leaflets unequal-sided (unsymmetrical) 41
  - Branches unarmed:
    - *Leaflets evergreen;* fruit a pod (contracted between the beans) with red, white-scarred beans 38
    - *Leaflets deciduous;* fruit not a pod:
      - Leaflets unequal-sided and often not quite opposite on the leaf-stem 33
      - Leaflets equal-sided and opposite on the leaf-stem:
        - Leaflets 3; fruit in clusters, a flat, light-colored seed with a wing all around (resembles an Elm-seed) 28
        - Leaflets more than 3; fruit berry-like or a nut:
          - Leaflets long-pointed; fruit a nut with a wrinkled shell. 66
          - Leaflets short pointed:
            - Fruit, berry-like, red, in flat clusters 52
            - Fruit not berry-like—3 dark, shiny nuts in a 3-lobed husk 32
- B.—Leaves set *opposite*[3] on the branches.
  - Wood with a large, white, soft pith; fruit (berries) black, but white with bloom, clustered 56
  - Wood with a small, dark, rather hard pith; fruit (seed a thin-winged key:
    - Leaflets 3 to 5; seeds (keys) in pairs, but separable: Box-elder 36
    - Leaflets more than 5; seeds (keys) single; ASHES:
      - Leaflets smooth and green on both sides 60
      - Leaflets smooth and green above, but more or less downy on the underside:
        - Inner bark of the branches red; young shoots and leaf-stems rusty-velvety:
          - Mature seeds (keys) 1½ to 2 inches long 59
        - Inner bark of branches not red; young shoots and leaf-stems downy (not rusty):
          - Mature seeds (keys) ¾ to 1⅝ inches long 58

YUCCAS.

[Trees with unbranched trunks and wood not in annual layers—a mingled mass of fibers.]

- Leaves 1 to nearly 3 feet long:
  - Less than ½ an inch wide 67
  - More than ½ an inch wide (1½ to 2 inches) 68

CONIFERÆ: PINE FAMILY.

1.—WHITE PINE. "MOUNTAIN PINE." (*Pinus monticola*, Douglas.)

A large and important timber tree, occurring in northern Montana and Idaho (also in southern British Columbia, and from Washington Territory to southern California) between 3,000 and 10,000 feet elevation, usually occurring on a poor, sandy soil. In northern Montana it attains, perhaps its most valuable size, 60 to 100 feet high and over 3 feet in diameter. The wood is quite similar to that of the White Pine of the Northeast (*Pinus strobus*, Linn.), and is used considerably for lumber throughout its range.

Description.—Leaves in fives (with small distant teeth) often 3 to 4 inches long. Cones 5 to 8 inches long (on long stems), slender, cylindrical, yellowish-brown; pendulous the second year; seeds small, light-colored. Bark pale, rather smooth, breaking up into squarish plates. (Distinguished from *Pinus strobus* by its longer cones and stiffer leaves.)

2.—WHITE PINE. (*Pinus flexilis*, James.)

Next to the Bull Pine (No. 7) in its general distribution, on dry, rocky, ridges; and, although its wood is inferior to that of the former, it is used for many of the same purposes; in parts of Wyoming and Montana furnishing most of the local supply of lumber for domestic purposes. Generally found growing on eastern slopes at altitudes from 4,000 to 10,000 feet, from Montana (probably much farther north) to New Mexico; (also in the Guadalupe and Limpia Mountains, western Texas; the high ranges of Utah, Nevada, northern Arizona, and in the Inyo Mountains and Mount Silliman, California.) It attains a height of 50 to 75 feet, with a diameter of 3 feet and over.

Description.—Leaves in fives, 1½ to 2 (exceptionally 2½ to 3) inches long. Cones on very short stems, oval or rather cylindrical, 3 to 5 inches long and light brown; scales spreading widely at maturity. Crown roundish; branches drooping; bark furrowed and gray.

3.—HOARY-BRANCHED PINE. (*Pinus albicaulis*, Engelm.)

A tree of little economical importance, as it rarely attains a useful size. It has a limited range in the Rocky Mountain region, occurring only on high ridges in northern Montana (but on the Pacific coast extends from southern California to British Columbia). It grows in dry, gravelly soil, reaching up to the extreme line of timber growth, where it becomes a shrub; sometimes 40 feet in height and 1 to 1½ feet in diameter, though generally smaller where it occurs in greatest abundance. Wood light and soft.

Description.—Leaves in fives (and fours), 1¼ to 2½ inches long. Cones 1½ to 3 inches long; their few scales thickened at the end and the blunt tip turned up; scales falling away after the cone is ripe; purple when young, reddish-brown at maturity. Bark milky white, especially on smaller branches.

4.—WHITE PINE. (*Pinus reflexa*, Engelm.)

Only sparingly distributed through southwestern New Mexico and southeastern Arizona, usually on rocky slopes between 6,000 and 8,000 feet. It reaches a height of 60 to 90 feet, with a diameter of 2 feet; is generally a taller and more slender tree than the more northern White Pines. The wood is light, hard, very flexible, but little used for lumber.

Description.—Leaves in fives (and fours), slender, 2¾ to 4 inches long. Cones 6 to 8 inches long, on thick stems, ½ to 1½ inches long, and erect the first year, but recurved the second. Seeds large, flattened, wingless; sweet as those of the Nut Pine (*Pinus edulis*, Engelm). Trunk slender, of ten crooked, with few branches at top.

5.—PIÑON PINE. NUT PINE. (*Pinus edulis*, Engelm.)

A small tree, but of considerable importance throughout its range, extending through southern Colorado, New Mexico, and western Texas, generally occupying sand and limestone slopes up to 9,000 feet. Said to be found also in southern Wyoming. Varies much in size, from 20 to 50 feet, but oftener about 25 feet, with a diameter of 1 to 2 feet. The wood is light, soft, and quite durable when exposed to moisture. It is especially valuable for fuel, for which it is extensively used, as also for manufacturing charcoal, and for fencing; occasionally used for poor quality of lumber.

Description.—Leaves chiefly in twos, 1 to 2 inches long, rigid, much curved or straight. Cones 1½ to 2 inches long, globose; ends of the few scales prolonged into a truncate-pyramidal tip; light russet color at maturity. The seeds (nuts) are sweet and edible. Generally a low tree with round crown and bushy habit.

6.—FOX-TAIL PINE. HICKORY PINE. (*Pinus Balfouriana* Murray, var. *aristata*, Engelm.)

Rather rare, occurring chiefly in Colorado (but westward through Utah, Nevada, and southeastern California) on dry rocky ridges between 7,500 and 12,000 feet. It attains a height of from 50 to 100 feet, with a diameter of 3 to 8 feet. The wood is hard, tough, of a reddish color, and where found in the mining districts has been much employed for timbering mines, and to some extent for lumber.

Description.—Leaves in fives, 1 to 1¼ inches long, curved toward and closely pressing the branch. Cones terminal, oval; purple when young, russet-brown at maturity; 2½ to 3½ inches long, with delicate prickles, which are recurved as the cone matures. Bark reddish gray.

7.—BULL PINE. YELLOW PINE. HEAVY-WOODED PINE. (*Pinus ponderosa*, Dougl.)

The predominant and most generally distributed tree of the Rocky Mountain region, and for commercial purposes the most important. It is among the hardiest of the Conifers, and grows in the most arid and exposed sites, usually occupying southern exposures. It occurs at elevations between 4,500 and 6,500 feet. It does not attain as large a size in the Rocky Mountains as in the California Sierras, although in Montana sometimes reaching 100 feet in height, and 6 to 7 feet in diameter. The wood is quite resinous, of a reddish color, with a handsome grain, and is largely employed for lumber, railroad ties, mining timber, and somewhat for interior finish.

Description.—Leaves in threes (often in twos), 3 to 6 inches long, brush-like at the ends of the branchlets; persistent three years. Cones 2 to 3 inches long (or more), gray-brown, with strong prickles. Bark very thick, in old trees, 3 to 4 inches.

8.—CHIHUAHUA PINE. (*Pinus Chihuahuana*, Engelm.)

Somewhat rare and of limited range; found on rocky slopes of southwestern New Mexico (extending into southern Arizona and northern New Mexico), at elevations between 5,000 and 7,000 feet; 30 to 70 feet high, 1½ feet in diameter. Wood light and strong.

Description.—Leaves mostly in threes (twos and fours also), 2½ to 3½ inches long: cones on stems ½ to ⅔ an inch long, 1½ to 2½ inches long; dark brown, with short delicate prickles.

9.—BLACK PINE. LODGE-POLE PINE. TAMARACK. (*Pinus Murrayana*, Balfour.)

Rather abundant throughout the Rocky Mountain region, extending westward and northward, but more common in the northern portion, forming large forests of pure growth. It is said, however, to attain its greatest size in southern California—60 to 100 feet, with a diameter of over 3 feet.*

Usually found growing in slightly moist or dry gravelly soil between 6,000 and 9,000 feet elevation. The wood is soft and light, not unlike that of the White Pines; employed to some extent for lumber, railroad ties, and much for "lagging" in mines.

Description.—Leaves in twos, 1 to 3 inches long, but chiefly 2 inches, with fine teeth. Cones 2 to 3 inches long, reflexed, and with delicate recurved prickles. Bark very thin and scaly, grayish-brown. Crown conical. Resembles the Scrub Pine (*Pinus contorta*, Dougl.), but distinguished from it by having longer and wider leaves, as well as by a much thinner bark.

10.—WHITE SPRUCE. SINGLE SPRUCE. (*Picea alba*, Link.)

A large and important timber tree, growing in rather wet soil on the borders of ponds and streams, reaching over 100 feet in height and 2 to 3 feet in diameter. In the Rocky Mountain region it occurs only in northern Montana, and attains its greatest size in the Flathead region at altitudes of 2,500 to 3,500 feet. (From British Columbia and northward the range of this species extends along the northern boundary of the United States to Maine and northward.) Extensively used for lumber, and as such not distinguished from that of the Black Spruce (*Picea nigra*, Link.), with which it is much associated in its northern distribution.

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* When growing in thickets it is often imperfectly developed, and is called "Lodgepole Pine;" such trees sometimes being over fifty years old, with a diameter of not more than 6 to 8 inches.

Description.—Leaves ¼ to ¾ of an inch long, stiff, erect, or curved. Cones nearly sessile or on stems $\frac{1}{10}$ to ¼ of an inch long; 1 to 2 inches long, cylindrical or oblong; scales with entire margin.

11.—ENGELMANN'S SPRUCE. WHITE SPRUCE. RED SPRUCE. (*Picea Engelmanni*, Engelm.)

The most valuable timber tree in the Rocky Mountain region, forming large forests. It ranges from New Mexico to Montana (westward and north of the United States boundary), usually seeking dry gravelly ridges between 5,000 and 11,500 feet; in Colorado, where it attains its greatest size, occurring at elevations from 9,000 feet up to the timber line; 100 to 130 feet in height, and over 3 feet in diameter; but at the highest limit of growth only a prostrate shrub. The wood is tough, strong, and elastic. Nearly all the rough and dressed lumber used in the Rocky Mountain region is of this spruce. It is best adapted to inside work, but when well seasoned and protected with paint can be used outside; is said to warp and crack too much for good shingles. The wood is also largely used for fuel and charcoal. Bark valuable for tanning.

The spruce forests in the Rocky Mountain region are very important in holding the snow and preserving a flow of water in the streams. Thus the snow is often retained as late as the 1st of August; and the growing season for these trees does not average more than two months.

Description.—Leaves ½ to $\frac{9}{10}$ of an inch long, strongly keeled, and awl-pointed. Cones ovate-cylindrical; 1½ to 2¾ inches long, and ¾ to 1 inch in diameter; on stems ¼ to ¾ of an inch long; reddish brown when mature; scales thin, horny, rhomboidal, with truncate tip, which is entire, with two to three small teeth, or rounded. Branches mostly short and small. Bark scaly, grayish, or reddish-purple.

12.—BLUE SPRUCE. WHITE SPRUCE. "BALSAM." (*Picea pungens*, Engelm.)

A local and somewhat rare tree occurring in central Rocky Mountain region—Wyoming, Colorado, and Utah—between 6,000 and 9,000 feet. It prefers a damp soil, and grows rapidly in such situations, attaining a height of over 100 feet, with a diameter of 3 feet or more. The wood is light, soft, weak, and probably of little value. The trunks taper too rapidly to be cut into lumber to advantage.

Description.—Leaves ½ to $\frac{9}{10}$ of an inch long, rigid, 4 angled, needle-pointed. Cones light reddish-brown, 3½ to 4 (often 5) inches long, by 1½ inches in diameter; scales very thin, rhomboidal, truncated, with wavy, irregular, or entire margin. Bark grayish on large trees, very thick and furrowed; that of the branches rather smooth and glossy. A beautiful tree, of fine ornamental appearance, with more or less silvery-white foliage and sharply-tapering crown.

13.—BALSAM FIR. BALM-OF-GILEAD FIR. (*Abies balsamea*, Miller.)

A rather small tree growing in damp or swampy sites of the Rocky Mountains of Idaho and Montana (found also in northeastern United States and north of boundary). It is a short-lived tree, and owing to the small size, lack of strength, hardness, and durability of its wood of little importance as a timber tree; 50 feet in height, and 1 foot or more in diameter; at high elevations much reduced in size.

Description.—Leaves sessile, ¼ to 1 inch long, narrow, flat, with small notch at the tip and white lines above, a silvery tinge below; thickly spreading, somewhat regularly in spirals on all sides of the branches, but on horizontal twigs, crowded chiefly on the upper side. Leaf-scars oval, prominent, lasting. Cones 2 to 4 inches long, 1 to 1½ inches in diameter, upright on short footstalks (upper branches), cylindrical, tapering slightly; scales blue-purple, broad, roundish, entire, each with an accompanying outside bract. Branches chiefly in whorls of about five.

14.—BALSAM. (*Abies Subalpina*, Engelm.)

A tall, slender tree much isolated and rarely forming forests. Generally growing in gravelly soil of slopes and canyons between 4,000 and 12,000 feet elevation. It occurs in the mountain ranges of Utah, and from Colorado to Montana (westward to Oregon and Washington Territory, and north of United States boundary). It seldom attains more than 100 feet in height, and from 2 to 3 feet in diameter. The wood is very soft and light, possessing little strength.

Description.—Leaves of the lower branches usually long, narrow, and blunt, in two ranks; those of the upper young branches *shorter*, much broader, thicker, acutely pointed, attached by a *broad base*, dense, somewhat in two ranks; whitish beneath; $\frac{7}{10}$ to 1½ inches long. Young branches with longitudinal ridges.

15.—GREAT SILVER FIR. WHITE FIR. (*Abies grandis*, Lindley.)

A very large and important timber tree occurring in Bitter Root Mountains, Idaho, and in ranges of northwestern Montana (also on Pacific coast from latitude 40° to boundary of United States and northward); 250 to 300 feet high, with a diameter of 4 to 5 feet. It prefers bottom-lands and northern and western slopes below 4,000 feet, but producing the largest timber in the former situations. It is perhaps of greatest importance in the northern Pacific region, where it is said to attain its largest dimensions, and is employed considerably for lumber. The wood, however, is light, soft, and quite inferior to that of the Douglas and Sitcha Spruce.

Description.—Leaves ½ to 1½ inches long, narrow, flat, channeled, blunt, with a small notch at the tip, comb-like in arrangement, an upper and lower horizontal rank on each side of the branchlets; leaves of lower rank much longer; glossy and with two white lines beneath. Cones solitary, 2 to 5¼ inches long, cylindrical, on very short footstalks; scales *very broad*, entire. Bark scaly and brownish.

16.—WHITE FIR. BALSAM FIR. BLACK BALSAM. (*Abies concolor*, Lindl. and Gordon.)

Found in New Mexico and southern Colorado (westward in central Utah, northern Arizona, southern California to Oregon). It is most abundant along the Pacific coast, occupying moist slopes and canyons, between 3,000 and 9,000 feet elevation. It commonly grows to a height of 100 feet, with a diameter of 4 feet and over. The wood is soft, very light, and little used for lumber, except in temporary constructions, and for domestic purposes.

Description.—Leaves ½ to 2, sometimes 3 inches long, thick to thin, flat, blunt to awl-pointed, or slightly notched at the tip; in two ranks, chiefly on the upper side of the branchlets; pale green, whitish beneath. Cones nearly sessile, 2¾ to 5 inches long, and 1¼ to 2¼ inches in diameter; ovate, cylindrical, pale green, dull purple, or light reddish brown; scales ¾ to 1½ inches broad. Bark light gray. Branches quite regularly in whorls.

17.—WESTERN HEMLOCK. (*Tsuga Mertensiana*, Carrière.)

A Western representative of the Eastern Hemlock (*Tsuga Canadensis* Carr.), but much larger and with finer-grained wood. It ranges from western Montana westward to the Pacific coast, and north of the United States boundary; southward on coast through northern California, forming large forests at elevations between 1,000 and 4,000 feet. It is quite adaptive in point of soil conditions, thriving on poor dry ridges, but prefers a moist soil. Probably reaches its greatest development in Oregon and Washington Territory; 180 feet high, and 6 to 8 feet in diameter. The wood is rather heavy, hard, and quite free from resin, but somewhat lacking in strength; employed to some extent for coarse lumber, while the bark supplies an important demand for tanning.

Description.—Leaves flat, very narrow, ⅓ to ¾ of an inch long, blunt at the top, tapering suddenly to a slender stem (petiole). Cones ovate-cylindrical, ½ to ¾ of an inch long, light brown, with delicate pubescence; sscale few (and much longer than those of *Tsuga Canadensis*). Crown roundish to somewhat conical; branchlets numerous, slender, drooping.

18.—*Tsuga Pattoniana*, Engelm.

An alpine species having about the same range as the Western Hemlock (*Tsuga Mertensiana*, Carr.). It occupies dry slopes and ridges between 2,700 and 10,000 feet, but is reduced to a shrub as it approaches the timber-line. The wood is light and soft.

Description.—Leaves ½ to ¾ of an inch long, about four-angled, rather sharp-pointed, or blunt tapering to a stem at base. Cones 2 to 3 inches long, cylindrical-ovate. Bark thick, much cracked, reddish-gray; branchlets pubescent.

19.—DOUGLAS SPRUCE. "RED SPRUCE." YELLOW FIR. RED FIR. OREGON PINE. (*Pseudotsuga Douglasii*, Carrière.)

A remarkably large and one of the most important timber trees, quite generally distributed throughout the Rocky Mountain region entolis

(along the Pacific coast and north of the United States boundary). It is largely associated with pine, forming pure growths only in a few localities, and then of small extent. It grows from the sea-level to 10,000 feet, attaining from 200 to 300 feet in height and 10 feet in diameter. The wood is hard, strong, and durable, being especially valuable for large timber and coarse lumber, where durability and strength are needed.

Description.—Leaves, comb-like in arrangement, ½ to 1½ inches long, slender, flat, with stems, rather blunt-pointed; whitish on the under surface. Cones 2 to 4 inches long, 1 inch in diameter; somewhat cylindrical or ovate, with a fringe of three-pointed bracts from among the scales. Seeds reddish brown on one side, white on the other. Bark grayish brown: when young, smooth; in old trees rough, deeply furrowed, and sometimes over 1 foot thick.

20.—WESTERN LARCH. TAMARACK. (*Larix occidentalis*, Nutt.)

A western representative of the northeastern Tamarack, but a much larger, and in some respects a more valuable, tree. It is found in western Montana (also ranging westward in Oregon and Washington Territory and north of the United States boundary), usually occupying moist slopes between 2,500 and 5,000 feet. It is almost always associated with other species, and rarely, if ever, forming pure growths. In Montana it attains its most valuable size, reaching a height of 100 to 150 feet, with a diameter of 4 feet or over. The wood is heavy, very hard, strong, and durable, and is employed somewhat for lumber, but chiefly for posts, ties, fuel, etc.

Description.—Leaves 14 to 20 in a bundle, ½ to ¾ of an inch long, narrow, somewhat four-angled, slender at the base, pointed at the tip; pale green. Cones ovate-globose, ¾ to 1¼ inches long, by ¾ of an inch in diameter; solitary, erect or bent down; scales few, ⅓ of an inch long, roundish, loosely overlapping, squarish or notched at the tip, shining on the back; an elliptical, finely-toothed, acutely-pointed bract extending from the base and beyond the point of each scale, chiefly the long points only being visible beyond the ends of the scales. *Larix Europaea* and *Lyallii* also have an extended bract, but of different form. Branches, short; lower ones horizontal, upper ones ascending. Young shoots smooth, with many round black buds.

21.—*Larix Lyallii*, Parlatore.

A strictly alpine species, of small size, growing in dry rocky situations of northwestern Montana (and westward) at elevations between 5,500 and 7,000 feet; generally much scattered and associated with other conifers. The timber is little used, on account of its inferior size and the usually inaccessible positions occupied by it.

Description.—Leaves ¾ of an inch long, 40 to 50 in a bundle, very narrow, on young shoots single and longer. Cones 2 inches long, ovate-oblong (only immature specimens examined) and 1 inch in diameter; deciduous, greenish purple; margin of scales woolly-fringed; awl-pointed bracts from among and longer than the scales, the broad bases of the bracts being visible. Much branched; young shoots and buds clothed with a whitish wool.

22.—CANOE CEDAR. RED CEDAR. YELLOW CEDAR. (*Thuya gigantea*, Nutt.)

A large-sized tree and one of great economical importance. It occurs in northwestern Montana (and from California to Washington Territory and north of the boundary), growing chiefly in moist, but sometimes in dry, situations up to an elevation of 5,000 feet. In the northern Pacific coast region it reaches its most valuable dimensions—100 to 130 feet, and 6 to 9 feet in diameter. The wood is soft, light, and lacking in strength, but furnishes excellent material for inside work, as well as for coarse lumber, shingles, staves, etc.

Description.—Leaves short, scale-like, pointed, somewhat closely overlapping, and forming *short* internodes; no glands or tubercles (or very obscure); bright to glaucous green. Cones ½ of an inch long, ovate, of few scales, clustered at the ends of the branches, drooping; seeds winged all around. Crown narrow, pyramidal; branches spreading and somewhat drooping. Liable to be confounded with the California White Cedar (*Libocedrus decurrens*, Torrey).

23.—*Cupressus Guadalupensis*, Watson.

Little is known of the economic importance of this tree, as it is a comparatively new species, discovered in eastern Arizona in 1880. It occurs in southeastern New Mexico, eastern and southeastern Arizona, and southward, forming dense forests on rocky sites of from 5,000 to 8,000 feet elevation. It commonly grows to a height of 40 to 70 feet, and 2 to 4 feet in diameter. The timber is light and straight-grained, and splits very readily; the heart-wood resembles that of the Red Cedar very closely. In mining districts it has been employed considerably for wood and charcoal.

Description.—Leaves small, scale-like, opposite, appressed, overlapping, and forming short 4-angled branchlets, whitish (glaucous), free from pits or glands. Cones globe-like 1 to 1¼ inches in diameter, composed of from 6 to 8 thick, plate-like scales with large curved bosses, crowded on short, strong, footstalks. Bark dark red and fibrous, showing bright vermilion surface when newly scaled off. Closely grown, it is a tall and straight tree, but shorter and with greater ambitus when isolated.

24.—JUNIPER.* (*Juniperus pachyphloea*, Torrey.)

A tree 30 to 50 feet high and 3 feet or more in diameter, occurring in southern Arizona, New Mexico (in the mountains of western Texas, and southward into Mexico). It is confined chiefly to dry slopes and ridges between 2,000 and 3,000 feet, and in its mountain range is the principal juniper, especially in Texas. The wood is light, soft, and easily wrought. Fruit an important article of food among the Indians of the Southwest.

Description.—General aspect white. Leaves in threes, overlapping closely, rather sharp-pointed, ridged on the back, with a gland in the center; very glaucous. Fruit solitary, globe-like, ¼ of an inch in diameter, brownish, white with bloom, sweetish, borne at the ends of short erect branchlets, the latter somewhat four-angled.

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* See non-arborescent Junipers, page 197.

25.—"ROCKY MOUNTAIN JUNIPER." (*Juniperus occidentalis*, Hooker, var. *monosperma*, Engelm.)

A scraggy, stunted tree, occupying low, dry hills between 3,500 and 7,000 feet elevation. It ranges through southern Colorado, New Mexico (and westward through southern Arizona to southern California). In some localities it forms pure growths, but is chiefly associated with the Nut Pine (*Pinus edulis*) and *Juniperus pachyphlœa*, together forming the principal timber growth of the hilly sections; 25 to 30 feet in height, and 1½ feet or more in diameter. Wood rather light and soft, but very durable in contact with the soil, and employed largely for fuel and fencing.

Description.—Leaves in twos (alternate opposite pairs) and threes, fringed. Berries blue-black or copper-colored, resinous-fleshy; one to two, or more, grooved seeds in each berry. Branches short, horizontal, and often from the ground.

26.—RED CEDAR. SAVIN. (*Juniperus Virginiana*, Linn.)

A valuable tree, and one of the most widely distributed of the North American Conifers. It is a very adaptive species, but the character of the soil has much to do with its success as a timber tree; in bottom-lands it reaches a height of nearly 100 feet, with a diameter of 3 feet or more, while in dry, barren soil it is a small, slow-growing tree, or little more than a shrub. In the Rocky Mountain region it occurs chiefly in the mountains of Colorado, Wyoming, Montana, and Idaho (also through eastern United States and north of the boundary). The timber is light, soft, and possesses remarkable durability in contact with the soil. It is employed principally for posts, ties, and cabinet work.

Description.—Leaves scale-like, in twos, sometimes in threes, mostly in alternate opposite pairs, of two forms: on young plants and shoots, needle-pointed and somewhat spreading; on mature branchlets, awl-pointed and closely overlapping; bright glossy green to tawny brown in winter; midrib indistinct. Branchlets slender, four-angled. Berries small, ovate, smooth, but with few small, scaly protuberances; whitish with bloom.

27.—YEW. (*Taxus brevifolia*, Nutt.)

A somewhat rare and small tree as it occurs at its eastern limit in the Rocky Mountains of western Montana and Idaho. In its more westerly range, however (through Washington Territory and Oregon to central California), it attains a much larger size, 40 to 70 feet in height and 1½ to 2½ feet in diameter. It generally prefers a moist, rich soil, and on the Pacific Coast is much associated with Lambert's Pine and the Douglas Spruce. The wood is hard, durable, and very elastic, and is used considerably for fence posts, tool-handles, bows, etc.

Description.—Leaves scattered, ½ to 1 inch long, narrow, flat, curved, sharp-pointed, ribbed above, on yellowish footstalks; yellowish glossy green above, whitish (*glaucous*) below. Fruit solitary, borne on the under side of the branches, amber-red or yellowish brow Branches long, slender, and pendulous; bark yellowish.

RUTACEÆ: RUE FAMILY.

28.—SHRUBBY TREFOIL. HOP-TREE. (*Ptelea angustifolia, Benth.*)

Chiefly a shrub, or sometimes a small tree 15 to 25 feet in height, with very slender trunk, usually growing on hillsides in dry, gravelly soil, through southern Colorado (extending southward into Mexico and Texas). Rarely attaining sufficient size to be of economic value. The wood is heavy and hard.

Description.—Leaves compound, composed of three leaflets, which are given off at the end of a slender (leaf) stem, 1 to 2 inches long and $\frac{1}{4}$ to 1 inch wide, lance to oblong-lance-shaped, usually tapering to a point at either end; margin entire or with shallow rounded teeth; smooth, old leaves shiny. Fruit (much like that of the elm) surrounded by an early orbicular, thin, veiny wing, $\frac{1}{4}$ to $\frac{5}{8}$ of an inch in diameter. Bark dark brown and often thickly dotted.

RHAMNACEÆ: BUCKTHORN FAMILY.

29.—BLUE WOOD. LOG WOOD. PURPLE HAW. (*Condalia obovata*, Hooker.)

A small tree or shrub, at best seldom more than 10 to 30 feet in height and with very slender trunk—3 to 6 inches in diameter. It is found in southern New Mexico (southern Arizona and southwestern Texas, where it is said to reach its greatest development), especially along streams. Abundant and in many localities forming dense, impenetrable thickets. The wood is hard and very heavy.

Description.—Leaves $\frac{1}{4}$ to $\frac{3}{4}$ of an inch long, by $\frac{1}{10}$ to $\frac{1}{2}$ of an inch wide, chiefly broad at the top end (obovate), tapering to a long point at the base; rounded at the upper end, or with a lance-shaped point. Branches with smooth thin bark of a dull white or grayish color; branchlets spine-like or terminating in a small sharp spine. Fruit a globular berry (drupe) with scanty flesh and large hard stone; a short point or beak (the persistent stigma) adheres to the end.

30.—"INDIAN CHERRY."* (*Rhamnus Caroliniana*, Walter.)

A small tree, 15 to 30 feet in height, with a trunk 6 to 10 inches in diameter; or sometimes reduced to a slender shrub. It is found in the mountains from Colorado to Montana (eastward it ranges from western Texas to northern Florida, and northeastward through the valley of the Ohio River to long Island, New York). It prefers the rich soil of bottom-lands and along streams; probably reaching its largest size in Texas and Arkansas. The wood is rather light and hard, but not strong.

Description.—Leaves 3 to 6 inches long, 1 to 2 $\frac{1}{4}$ inches wide; oblong lance-shaped or ovate-oblong; with rounded base and rather short point; margin wavy, nearly entire or with very small teeth; leaf-stems hairy. Flowers and fruit borne in the axils of the leaves, the latter black, somewhat pear-shaped, and with three large seeds; sweet and edible.

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* See *Rhamnus* in list of shrubs, page 190.

31.—BEARBERRY. BEAR WOOD. SHITTIM WOOD. (*Rhamnus Purshiana*, De Candolle.)

A shrub or small tree, 6 to 25 feet in height, and from 4 to 12 inches in diameter. It occurs in northern Montana and Idaho (also along the Pacific coast from northern California to Washington Territory). Generally associated with conifers in canyons and low places. The wood is light and hard, but brittle, being of little importance. The bark, however, has of late become an important article of of commerce, being extensively employed for officinal purposes under the name of *Cascara sagrada*.

Description.—Leaves chiefly alternate, elliptical, 1½ to 3½ inches long, 1½ to 1¾ inches broad, finely toothed on the margin, and somewhat downy below. The fruit is berry-like, black, 3-lobed, larger at the top, 3-seeded, and borne in clusters on rather long stems from the axils of leaves; about ¼ of an inch in length. Young branches and stems of the leaves woolly.

SAPINDACEÆ: SOAPBERRY FAMILY.

32.—SPANISH BUCKEYE. (*Ungnadia speciosa*, Endlicher.)

A shrub or small tree, 20 to 30 feet in height and 6 to 12 inches in diameter, found growing abundantly on moist bottoms and rich slopes of southern New Mexico (western Texas, and northern Mexico). The wood is soft, rather heavy, but lacking in strength. The fruit and leaves are said to be poisonous.

Description.—Leaves compound, composed of from 3½ to 5½ pairs of leaflets, which are on very short stems, ovate, lance-shaped, and with a rather long point; the margins have fine, or large and distant teeth; in length the leaflets vary from 2 to 4 inches and from ¾ to 1¾ inches in width. Shell of fruit thin, smooth, brown, strongly 3-lobed, containing as many dark, shiny nuts about ½ an inch in diameter. The flowers appear in advance of the leaves in small lateral clusters. Young shoots and leaf-stalks downy.

33.—WILD CHINA. SOAPBERRY. (*Sapindus marginaius*, Willdenow.)

A rather large and somewhat important tree, occurring in southern New Mexico (and Arizona; eastward through the Gulf States to the Atlantic coast). It grows chiefly in mountain valleys and river-bottoms, attaining its largest size in eastern Texas, 10 to 60 feet in height, with a diameter of ½ to 1½ feet. The wood is heavy, hard, and strong; it splits easily, and is extensively used in the manufacture of cotton baskets.

Description.—Leaves compound; leaflets nine to eighteen, arranged in opposite pairs or alternate, lance-ovate, hooked, unequal sided, unsymmetrical; veins prominent above. Fruit globular, berry-like, borne in the axils of leaves.

MAPLES.

34.—DWARF MAPLE. (*Acer glabrum*, Torrey.)

As indicated by its name, this species is seldom more than a shrub 3 to 6 feet high; occasionally it reaches a height of 10 to 20 feet, with a diameter of 4 to 6 inches. It is widely distributed throughout the Rocky Mountain region (on Pacific coast to British Columbia), growing along water-courses, in sheltered canyons, and on moist slopes; said to reach its best development in western New Mexico and eastern Arizona. The wood is heavy and hard. It is a very hardy tree and considerably used for ornamental planting.

Description.—Leaves somewhat kidney-shaped, 3-lobed to 3 parted; divisions themselves somewhat 3-lobed, middle one wedge-shaped, short, broad, margin sharply cut and toothed; smooth both sides. Generally branching from the ground.

35.—*Acer grandidentatum*, Nuttall.

A small and rather rare tree, found growing along water courses in western Montana and southern New Mexico (also in eastern Arizona and central Utah). It is seldom more than 20 feet in height and 4 to 10 inches in diameter. The wood is heavy and hard.

Description.—Leaves heart-shaped or cut straight across (truncate) at the base, somewhat deeply 3-lobed; divisions sharp-pointed and mostly entire, but occasionally with few coarse teeth; velvety on the under surface, or sometimes smooth.

36.—BOX-ELDER. ASH-LEAVED MAPLE. (*Negundo aceroides*, Mœnch.)

One of our most widely-distributed forest trees, occurring throughout the Rocky Mountain region at elevations between 5,000 and 6,000 feet (east of the Rockies to the Atlantic coast, and north of the U. S. boundary), preferring the more southerly ranges. It is adapted to a variety of soil conditions, but generally attains its best dimensions on moist bottom-lands and along streams. Commonly 30 to 60 feet in height and 1 to 3 feet in diameter. As an ornamental tree it is quite popular, being easily handled and reaching a desirable size in a comparatively short time.* The wood is of rather an inferior quality, being light, soft, and lacking in strength. It is little used for manufacturing purposes, except occasionally for interior lumber, and to some extent in turnery, cooperage, and for paper-pulp.

Description.—Leaves compound, composed mostly of 3 (sometimes 5) leaflets, which are ovate, pointed, often with entire margin, but usually coarsely toothed, and strongly veined; smooth or occasionally downy on the under surface. The flowers appear in advance of the leaves, and hang down in green, tassel-like clusters. The seeds are usually very abundant, and have long, curved, veiny wings, and hang in thick clusters on long slender stems. Young branches greenish.

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* It is also desirable as an admixture in forest planting, the heavy foliage furnishing a good soil cover.

LEGUMINOSÆ: PULSE FAMILY.

37.—LOCUST. (*Robinia Neo-Mexicana*, Gray.)

Usually a small tree, 20 to 25 feet, with a diameter of 3 to 6 inches; or a shrub under 6 feet in height. It occurs in southern Colorado, southwestern and western New Mexico (and in Arizona and southern Utah between 4,500 and 7,000 feet elevation). It is said to reach its best development in the valley of the Purgatoire River, southeastern Colorado. At high elevations often reduced to a shrub. The wood is heavy, very hard, and strong.

Description.—Leaves composed of from 4½ to 9½ pairs of elliptical leaflets, which are more or less clothed with a whitish silky down, especially prominent on very young leaves. Leaf-stems and branchlets thickly set with stiff, straight, glandular hairs, as also are the pods. The latter are flat, often jointed, and vary in length from ½ to 3¾ inches, with a width of not more than ½ an inch; the end of the pod terminates in a curved awn. Two rather strong thorns ¼ to ½ an inch long) at the base of each leaf-stalk. Flowers showy, purplish.

38.—FRIGOLITO. (*Sophora secundiflora*, Lagasca.)

Chiefly a shrub, forming dense growths along streams or growing sparingly on rocky hill sides; as a tree it is seldom more than 30 feet high, with a slender trunk. It extends from the mountains of New Mexico to the Gulf coast of Texas, and where large enough to be available its hard heavy wood is highly esteemed for fuel. Very ornamental in appearance.

Description.—Leaves compound, evergreen, with from 3½ to 5½—scarcely opposite—pairs of leaflets; the latter 1 to 2½ inches long and ½ to 1 inch wide, elliptic-oblong or ovate, with a wedge-shaped base and a usually rounded apex; margin entire, smooth, often shiny above; leaf-stems with a groove on top, and when young velvety, as are the flower-stems. Pods thick, woody, silky, with 1 to 2 speherical or elliptical (rarely 3 or 4 fertile) joints, which are ¾ of an inch in diameter and contain one or two red, very hard-shelled beans, bearing a deep white scar. They are said to have produced poisonous effects in persons who have eaten them, although the Angora goats feed upon the leaves of the plant and often swallow the beans without injury; but the shells of the latter are rarely, if ever, crushed by the animal's teeth.

39.—MESQUIT. ALGAROBA. HONEY-POD. HONEY LOCUST. (*Prosopis juliflora*, De Candolle.)

A tree of great economic importance. It is found in southern Colorado, and through New Mexico (to southern California; occuring also in western Texas, southern Utah, and Nevada, Mexico, and southward). Along streams and in valleys it sometimes forms forests of considerable extent, though never attaining a height of more than 50 feet, with a diameter of 1 to 2½ feet; commonly much smaller, and in dry rocky situations, especially those subject to annual burning, reduced to a shrub; but the root system is then enormously developed—locally termed "underground forests"—and furnishes a cheap and valuable fuel. The timber is heavy, very hard, and possesses remarkable durability. It is employed chiefly for fuel, tie-timber, and fencing, but somewhat for heavy wheel stock and in the manufacture of charcoal.

Description.—Leaves compound, twice pinnate, single or in clusters, with a pair of stiff, straight, yellowish thorns ¼ to ½ inch long at the base of each leaf-stalk or cluster; leaflets ¼ to 1¾ inches long, by 1/10 to ¼ of an inch wide, elliptic-oblong to lance-linear. A cup-shaped gland at the end of the main leaf-stem, (where the usually single pair of smaller stems (pinnæ) with leaflets is given off). Pods somewhat flattened, straightish or curved, 3 to 7½ inches long, ¼ to ½ an inch wide; composed of 12 to 25 lobe-like joints (containing as many seeds), and terminating in an awl-point; young pods covered with a dense velvety down, yellowish-white when mature. They have a sweet taste, and are often used for fodder.

40.—SCREW BEAN. SCREW-POD. MESQUIT. TORNILLA. (*Prosopis pubescens*, Benth.)

A small tree or shrub growing on gravelly or sandy bottom-land, through New Mexico (in western Texas, through Arizona to California; southward into Mexico); said to attain its largest size within the United States in the valleys of the lower Colorado and Gila Rivers—20 to 25 feet in height, and 6 to 12 inches in diameter. The wood is heavy, very hard, and brittle, but exceedingly durable, and is used for fencing and fuel. Pods sweet, sometimes used for fodder, and for flour by Indians.

Description.—Leaves essentially as in *Prosopis juliflora* (No. 39), with a pair of straight pearly-white thorns at base of each leaf or cluster; leaflets elliptic-oblong, often with a short fine point (probably less variable in size than those of the preceding species), ¼ to ½ an inch long, and 1/12 to ⅙ of an inch wide. Pods cylindrical, 1 to 2½ inches long, ⅙ to ¼ of an inch in diameter, straightish or crooked, closely coiled in a spiral; clothed with a fine velvety down; light brown at maturity. Branchlets with white longitudinal (decurrent) lines proceeding from the bases of the thorns.

41.—CAT'S CLAW. (*Acacia Greggii*, Gray.)

Often a shrub, or a low much-branched tree, 20 to 25 feet in height and sometimes 10 inches in diameter, growing abundantly on the dry table-lands and in the low canyons of southern Utah (Dr. Palmer), New Mexico and Arizona (extending to California; also in northern Mexico and western Texas). The wood is heavy, very hard and strong, furnishing good fuel. Large trees often hollow.

Description.—Leaf-stems short, giving off 2 to 3 pairs of smaller stems (pinnæ) which bear 3 to 6 pairs of very small (⅛ to ⅓ of an inch long) oblong-ovate (broader above) unequal-sided leaflets, with a rounded or abrupt apex, downy. Pods smooth, flat, curved, 3 to 6 inches long, and ½ to ¾ of an inch broad; usually with constrictions between the seeds; the latter flat, obicular, and dark brown. Branches sparingly armed with short hooked prickles, or occasionally unarmed, sometimes with whitish lines.

ROSACEÆ: ROSE FAMILY. CHERRIES AND PLUMS.

42.—WILD YELLOW OR RED PLUM. CANADA PLUM. HORSE PLUM. (*Prunus Americana*, Marshall.)

A small thorny tree, abundant, and forming thickets in dry or moist situations. It is seldom more than 15 to 30 feet high, with a diameter of 3 to 10 inches. In the Rocky Mountain region it is found chiefly in central Colorado, but has a wide range through the eastern United States and north of the boundary. It reaches its largest size in eastern Texas. The wood is heavy, very hard and tough, and is used occasionally for fuel, light tool-stock, etc. The fruit is often large, edible, and with a pleasant taste when fully matured. Sometimes cultivated or used for grafting stock.

Description.—Leaves 2 to 3 inches long, ovate, pointed, coarsely or finely toothed on the margin; smooth and with prominent veins when mature. Fruit somewhat spherical to ovoid in shape, ½ to 1 inch in diameter; dark, with reddish tinge and yellowish areas.

43.—CHICKASAW PLUM. HOG PLUM. (*Prunus angustifolia*, Marshall.)

Supposed to be a native of the eastern slopes of the southern Rocky Mountains, here found at elevations up to 7,000 feet. (But by cultivation it has become widely distributed eastward to the Atlantic coast, south of Pennsylvania.) It is a small tree, 20 to 30 feet in height, with a trunk 4 to 10 inches in diameter, or in some situations reduced to a shrub. It prefers a rich, moist soil, and is found growing chiefly along water-courses and the borders of rich woods. The wood is rather heavy, but soft and brittle. Cultivated considerably for its fruit.

Description.—Leaves 1½ to 2 inches long, thin, smooth, lance-shaped, with fine, sharp, incurved teeth on the margin. Fruit ½ to ¾ of an inch in diameter (borne on short stems), spherical, yellowish red, and with little bloom; thin-skinned, sweetish. Chiefly shrubby and inclined to be thorny.

44.—WILD RED CHERRY. PIN CHERRY. PIGEON CHERRY. (*Prunus Pennsylvanica*, Linn.)

Commonly a very small tree or shrub as it occurs in the Rocky Mountains of Colorado. In its eastern range through northern and central United States it becomes somewhat larger, but seldom more than 15 to 30 feet in height, and 6 to 12 inches in diameter. The wood is soft and light, and where large enough is occasionally cut for fuel. Fruit used sometimes for medicinal purposes.

Description.—Leaves 2 to 3½ inches long, ovate, lance-shaped, long-pointed, finely and sharply toothed on the margin; thin, shiny, green above and below. Fruit small, globular, very dark red; flesh scanty and sour. Bark reddish brown.

45.—OREGON CHERRY. (*Prunus emarginata*, Walpers.)

A tree sometimes 20 to 30 feet in height, and 4 to 10 inches in diameter, occurring abundantly along streams and in moist valleys of the mountainous portions of northern Idaho and western Montana (on Pacific coast and north of United States boundary), reaching elevations from 3,000 to 4,000 feet; but at high altitudes reduced to a shrub. Remarkable for the density of its growth, covering quite large areas. Variety *mollis* (Brewer) is the form commonly met with in the northern Rocky Mountain region. The timber is light, soft, and brittle.

Description.—Leaves oblong-ovate, or lance-shaped, chiefly with a blunt apex, tapering to a short stem; with small, rounded teeth on the margin, and woolly pubescence on the under surface. Fruit small, globular, red or blackish, with bitter astringent taste; not edible; stone with a grooved ridge on one side. Bark much like that of the common cherry tree of cultivation. Notable for its slender, straight trunks.

46.—WILD CHERRY. (*Prunus Capuli*, Cavanilles.)

A rather small tree, growing in light, rich soil of canyon bottoms, and ranging through Arizona, New Mexico (western Texas, and southward), usually between 5,000 and 7,000 feet. It is a very prolific species, but does not attain its largest size in the United States; commonly not more than 30 feet in height, with a trunk 3 to 10 inches in diameter. The wood is heavy and rather hard.

Description.—Leaves 1 to 3½ inches long, ovate to lance-shaped, sometimes with rather long tapering point; finely and sharply toothed on the margin; smooth, paler on under surface. Very young shoots and leaf stalks downy. Fruit globular, ⅝ of an inch in diameter, dark red, with large stone and scanty flesh; edible.

47.—WILD CHERRY. (*Prunus Demissa*, Walpers.)

Chiefly a small shrub as met with on the western slopes of the Rocky Mountains of Montana. In its more westerly range on the Pacific coast it becomes larger, sometimes 30 feet in height, and 6 to 12 inches in diameter, usually preferring rich valleys. The wood is heavy, hard, but brittle.

Description.—Leaves ovate to oblong-ovate, tapering suddenly to a point, rounded or heart-shaped at the base; sharply toothed (teeth straight) on the margin; commonly downy on the under side and dull green above. Fruit purplish or dark red, with sweetish-astringent taste; edible.

48.—CHOKE-CHERRY. (*Prunus Virginiana*, Linn.)

Chiefly a slender shrub, but sometimes a small tree 10 to 15 feet in height. A widely-distributed species, occurring generally throughout the northern Rocky Mountain region (also eastward and north of the United States boundary), usually preferring moist positions. The wood is light and rather hard.

Description.—Leaves thin, usually smooth and shiny above, paler beneath, 1 to nearly 5 inches long, mostly broad-ovate (wider near the top) to oblong, tapering suddenly to a short point at either end, sometimes heart-or wedge-shaped at the base; margin finely cut with sharp teeth (often of two sizes). Flowers (white) and fruit borne in a rather long cylindrical cluster (*raceme*); the latter when ripe ¼ to ⅜ of an inch in diameter), dark red, very astringent, though with more or less pleasant taste.

49.—*Canotia holocantha*, Torrey.

An anomalous shrub, or small tree, 10 to 20 feet high, and entirely without leaves. It occurs on the dry plateaus of Arizona, and probably in New Mexico. The wood is heavy and hard, but of little use except for fuel.

Description.—The branches are straight, spine-like, and peculiar for their smooth green bark with black scars. The seeds are borne in a solitary, erect, woody pod (1 inch long) with thin, sharp point, at maturity splitting open at the top, thus forming 10 bristle-pointed teeth; seed small, flat, dark, with a thin wing attached to one end.

50.—MOUNTAIN MAHOGANY. (*Cercocarpus ledifolius*, Nuttall.)

A low tree or shrub, rarely more than 35 feet in height and 2 feet in diameter; usually much smaller—10 to 20 feet. It generally grows on dry rocky slopes between 6,000 and 8,000 feet elevation, and is found in the mountain ranges of northern Idaho, western Montana and Wyoming, Arizona, and New Mexico (it occurs also on the Pacific coast from Washington Territory to southern California). The wood is dark, exceedingly heavy and hard, but not strong. It furnishes the most valuable fuel of the Rocky Mountain region, and is extensively employed in making charcoal.

Description.—Leaves ½ to 1½ inches long, narrow lance-shaped, sharp-pointed; margins entire, and commonly rolled back; thick, leathery, slightly resinous; smooth above, downy on the under surface; evergreen. Seed with a hairy tail 2 to 3 inches long. Usually a low and much-branched tree; crown dense.

51.—MOUNTAIN MAHOGANY. (*Cercocarpus parvifolius*, Nuttall.)

Chiefly a shrub, but sometimes attaining a height of 20 to 30 feet, with a diameter of 6 to 12 inches. It generally occurs on dry gravelly soil at elevations between 6,000 and 8,000 feet, ranging through the Rocky Mountains of Wyoming, Colorado, and New Mexico, where it is said to reach its largest size (southern Arizona and southward; also on coast of California and southward). Like the preceding species, it affords excellent fuel, and where large enough is used considerably for this purpose.

Description.—Leaves ½ to 1½ (commonly ½ to ¾ inch) long, on short stems; mostly wedge-shaped at the base, rather coarsely toothed at the upper end, which is rounded or sharp-pointed; young leaves with silky hairs above, with age less prominent or wanting; whitish on the under surface, with fine, dense wool; evergreen. Seed with a hairy tail 2 to 2½ inches long, sometimes 3½ to 4 inches.

52.—WESTERN MOUNTAIN ASH. (*Pyrus sambucifolia*, Cham. and Schlecht.)

Chiefly a shrub 6 to 10 feet high, or occasionally a small tree 20 to 25 feet, with a trunk sometimes 8 or 10 inches in diameter; usually confined to deep swamps and the banks of streams. In the Rocky Mountain region it extends from New Mexico to Colorado (westward to California, north to British Columbia and northward; eastward along the northern tier of States to the Atlantic), attaining its largest size in latter range. The wood is light, soft, and of no special value except for fuel.

Description.—Leaves compound, composed of from 3½ to 7½ pairs of leaflets, the latter varying in length from 1¼ to 3 inches, and in width from ½ to nearly 1 inch (exceptionally 1½ inches wide); mostly ovate-oblong or lance-shaped, and tapering suddenly to a short point at either end, or rounded at the top; margin sharply toothed (sometimes with teeth of two sizes), smooth. Fruit abundant, in flat clusters, berry-like, red, globular, ⅛ of an inch in diameter; together with the bark sometimes used officinally.

BLACK-FRUITED HAWTHORNS.

53.—*Cratægus rivularis*, Nuttall.

A shrub or small tree sometimes attaining a height of 10 to 20 feet, with a diameter of 3 to 10 inches. It occurs in the mountain ranges of Idaho, Montana, Utah, Colorado, to southern New Mexico (Pinos Altos Mountains), forming impenetrable growths along water courses and on the borders of swamps (it is found also in eastern Oregon, Washington Territory, and north of the United States boundary). The wood is hard, heavy, and tough.

Description.—Leaves ovate to lance-ovate, 1 to 3 inches long, ¾ to 2 inches wide, more or less wedge-shaped at the base, blunt or sharp-pointed; entire margin often with fine and coarse teeth, but chiefly confined to the upper part; smooth above, or with few delicate hairs, especially on the veins; pale below. Fruit blackish, ⅝ inch in diameter. Thorns few, rather short and thick, ½ to 1¼ inches long; seeds (nutlets) prominently ridged on the back. Generally much branched.

54.—*Cratægus Douglasii*, Lindley.

The most westerly of the thorns, occurring in Idaho, western Montana (and from northern California to Washington Territory and north of United States boundary). Sometimes 30 feet high and 10 inches in diameter. It prefers a somewhat moist sandy soil, forming dense thickets along streams and in valleys, reaching its largest size on the Pacific coast (Oregon) but chiefly a shrub in the Rocky Mountain region. The wood is heavy, hard, and tough, being locally used for wedges, mauls, etc.

Description.—Leaves 1¼ to 4 inches long, ¾ to 2½ inches wide, oblong-ovate to broadly ovate, with rounded, somewhat wedge-shaped, or sharply-tapering base; rounded or sharp pointed; entire margin sometimes with fine sharp teeth, or more often with large teeth above, which are themselves entire or finely toothed; smooth on the upper surface, or with few delicate silky hairs; pale beneath. Young branchlets and leaf-stalks woolly. Fruit ⅝ of an inch in diameter, black-purple, sweet, edible; often collected and eaten by the Indians; seeds (nutlets) strongly ridged on the back. Thorns short and strong, ¾ to 1¾ inches long.

55.—Black Thorn. Pear Thorn or Haw. (*Cratægus tomentosa*, Linn.)

One of the most widely distributed of the North American Thorns, varying much, and in size from a low shrub to a tree sometimes 30 feet in height and 1 foot or more in diameter, often forming dense growths along streams and in valleys. It is found in southwestern New Mexico, southwestern Colorado (eastern Washington Territory and Oregon; also ranging through the eastern half of the United States and north of the boundary). The wood is heavy and hard, but rather brittle.

Description.—Leaves varying in length from 1¼ to 4½ inches, and from 1 to 3 inches in width; oval to broadly ovate or slightly oblong-ovate, sharp-pointed or rounded; at the base tapering sharply, somewhat wedge-shaped, or rounded; margin usually cut with large teeth (sometimes lobe-like), which are themselves finely toothed (doubly serrate); upper surface smooth, or more or less downy, as are the leaf-and flower-stems. Fruit globular to slightly pear-shaped, ⅜ to nearly ¾ of an inch in diameter, light red or orange-colored; edible. Thorns 1 to 2½ inches long, thick and sharp.

CAPRIFOLIACEÆ: HONEYSUCKLE FAMILY.

56.—ELDER. (*Sambucus glauca*, Nuttall.)

A large shrub or tree, sometimes attaining a height of 20 to 25 feet, with a diameter of 6 to 12 inches. It is found abundantly in the Wahsatch Mountains of central Utah, usually along valleys in a dry soil, but is met with chiefly on the Pacific coast, extending from Mexico to British Columbia and northward. The wood is light, soft, and little esteemed. As an ornamental tree it is quite popular, being used considerably for this purpose.

Description.—Leaves compound, with 2½ to 4½ pairs of ovate or oblong lance-shaped leaflets, which vary in length from 1½ to 4½ inches, and in width from ¾ to 1½ inches; base of the leaflet acute and often with unequal sides (*unequilateral*); apex usually with long thin point; margin sharply toothed; generally smooth (but sometimes slightly pubescent). Fruit in a flat-topped cluster, black, but covered with a *dense white bloom*—a striking characteristic. Pith of young branches white.

OLEACEÆ: OLIVE FAMILY.

57.—"SINGLE-LEAF ASH." (*Fraxinus anomala*, Torrey.)

Abundant on shady hillsides and plateaus. A small tree, rarely more than 20 feet in height and 3 to 6 inches in diameter, occurring in southern Utah and southwestern Colorado. The wood is hard, heavy, and coarse-grained.

Description.—An anomalous species, lacking the usual compound leaf peculiar to other ashes. Leaves simple, opposite, 1 to 2 inches long, ovate, orbicular or heart-shaped (chiefly the latter), often with a broad notch at the end, mostly rounded above or with short point; margin entire or with shallow, rounded teeth; sometimes smooth, but usually more or less downy on the under surfaces, as are the leaf-stems and young shoots, but more densely so. Seeds ¾ to ⅞ of an inch long, ovate, pointed at the base, rounded and with notch above, strongly veined in the center. Young shoots often strongly quadrangular, with thin raised ridge (wing) at the angles.

58.—(*Fraxinus pistaciæfolia*, Torrey.)

A small but rather abundant ash occurring along streams and on rocky plains, often growing in the crevices of rocks where there is but little soil. It ranges through southern New Mexico (southern and eastern Arizona; also in southern Nevada, in the mountains of western Texas, and south into Mexico). Thirty to 40 feet, with a diameter rarely more than 1 foot. The timber is heavy, coarse-grained, and decays rapidly, but is apparently useful for many of the same purposes as the eastern White Ash; sometimes employed for wagon-stock, handles, etc.

Description.—Leaves compound, with from 2½ to 3½ pairs of leaflets, the latter varying much in size and form; 1 to 4½ inches long, ¼ to 2 inches wide, ovate to narrowly lance-shaped; margin sometimes entire, but chiefly with short, shallow, distant teeth; smooth above and below, but latter surface often downy, the veins always more or less so, as also are the young shoots and leaf-stems. Seeds ¾ to 1⅝ inches long, narrow, with a spatulate wing at the end, which is rather broadly notched, rounded, or with sharp point; abundant. Branches round.

59.—Red Ash. (*Fraxinus pubescens*, Lam.)

A rather small tree, 30 to 40 feet in height, with a diameter seldom more than 1½ feet; very rare in the Rocky Mountain region (being found chiefly in the northern and Atlantic States); generally growing along water-courses and in swampy situations. The wood is rather heavy, hard, and strong, but large timber is often brittle and much inferior to that of the White Ash, though occasionally used for the same purposes as the latter.

Description.—Leaves compound with 3½ to 4½ (commonly the former) pairs of leaflets, varying in length from 3 to 5 inches, and in width from 1 to nearly 2 inches; ovate to oblong—lance-shaped, with rounded base and rather long, thin point; margin chiefly entire, but sometimes with shallow or indistinct teeth; smooth above and woolly beneath; leaf-stems and young shoots rusty-velvety. Seed 1½ to 2 inches long, narrow and pointed at the base, broadening into a narrow wing above ¼ of an inch or less in width. Freshly parted bark of the branches reddish.

60.—Green Ash. (*Fraxinus viridis*, Michx. f.)

A middle-sized tree of considerable importance on account of its adaptability to various situations, though in its natural state found mostly in rather moist soil of bottoms and along streams. It occurs in the eastern Rocky Mountain ranges of Montana, Wahsatch Mountains (in central Utah), and in the ranges of eastern and northern Arizona (eastward it is found along the Atlantic coast and north of the United States boundary). Forty to 60 feet in height and 1 to 1½ feet in diameter. The wood is heavy, hard, and strong, often coarse-grained, and although generally inferior in quality to that of the White Ash, it is used as a substitute for the latter.

Description.—Leaves compound, with 2½ to 4½ pairs of leaflets, which are 2 to 5½ inches long and from ½ to 1¾ inches wide; ovate, oblong-ovate to lance-shaped, often with long tapering point, sometimes rather wedge-shaped or rounded at the base:

margin entire, with acute or blunt teeth, or sometimes with teeth only near the point; smooth and green both sides, but with fine, close down on midrib below. Seeds 1 to 1⅝ inches long, ¼ to ½ (commonly ¼) of an inch wide, slender and sharp-pointed at the base, broadening into a lance-shaped or spatulate wing above; ridged Branches round. Young seedlings *smooth* and *straight.*

BIGNONIACEÆ: BIGNONIA FAMILY.

61.—"DESERT WILLOW." (*Chilopsis saligna*, D. Don.)

A small shrub or tree, 10 to 25 feet in height and 4 to 10 inches in diameter, growing only near water, and preferring a light sandy soil. It occurs through southern Arizona and New Mexico (west into southern California, east into Texas, south into northern Mexico). The wood is light, soft, and much like that of the Black Walnut, but lighter, and very suitable for cabinet-work, though large trees are apt to be hollow and useless for lumber.

Description.—Leaves alternate, 1½ to 5½ inches long, commonly less than ¼ inch wide; linear to linear-lance-shaped, usually tapering to a very slender point at either end. Flowers large, (2 inches long) white or purplish. The seeds are borne in a long slender pod (like the Catalpa bean), 6 to 12 inches long; seeds small, flat, and with a thin brush of whitish wool at each end.

URTICACEÆ: NETTLE FAMILY.

62.—WHITE ELM. AMERICAN ELM. WATER ELM. (*Ulmus Americana*, Linn.)

A large tree, attaining a height sometimes of over 100 feet, with a diameter of 4 to 6 feet. It occurs sparingly in the northwestern Rocky Mountain region (but has an extended range east of the Rockies to the Atlantic and somewhat north of the United States boundary); very adaptive to different soils, but preferring moist bottom-lands, where it reaches its largest size. The wood is heavy, rather hard, and tough, often very difficult to split; in its eastern range used considerably for coarse lumber, flooring, staves, wheel-stock, and fuel. When employed for lumber, it requires care in seasoning to prevent it from warping badly. Often used as an ornamental tree.

Description.—Leaves 2 to 4 inches long, oval or oblong (broader above), tapering suddenly to a short, narrow point; base rounded (unequal-sided—peculiar to elms); margin sharply cut with teeth of two sizes; smooth above, hairy below, though often becoming smooth. Fruit (*samara,* ½ inch long) with thin wing all around, borne on drooping stems in small clusters; ovate, with a notch at the apex closed by two incurved teeth; margin of the wing with hair-like fringe. Branchlets and buds smooth. Large tree, with thick, grayish, and deeply furrowed bark; with room, producing low trunk, and a broad, much-branched crown; closely grown, the latter is contracted and the trunk tall and straight.

63.—Western Sugar-berry. Hack berry. Palo Blanco. (*Celtis occidentalis*, Linn., var. *reticulata*.)

A rather small tree, usually growing along streams in high mountain canyons, or in less favorable situations reduced to a shrub. It occurs from the mountains of southern Arizona through the Rocky Mountains to eastern Oregon; sometimes 30 feet high, with a trunk 18 inches in diameter, but mostly with a short, thick trunk, and branching near the ground, thus furnishing but little good timber, although the latter is sound, heavy, hard, and desirable for turnery. The wood is not generally distinguishable from that of the type which is found farther east.

Description.—Leaves thickish, 1 to 2½ inches long and ¾ to 1½ inches wide, mostly heart-shaped, with an acute apex, sometimes ovate lance-shaped; base often with unequal sides (oblique); margin entire or sharply toothed; upper surface *rough*, with *fine, sharp* teeth pointing toward the apex; usually with soft pubescence below or roughish on the veins, which are peculiarly joined into a net-work (*reticulate*). Fruit globular, cherry-like, reddish-yellow (purple with age), ¼ of an inch in diameter, with large stone and scanty flesh (sweetish); on slender stems, ¼ to ½ of an inch long from axils of leaves. Young shoots hairy. Resembles an Elm in its general appearance.

64. Mexican Mulberry. (*Morus microphylla*, Buckley.)

A small tree, sometimes 20 to 25 feet high and 6 to 10 inches in diameter, or reduced to a shrub. It occurs most commonly in the mountain canyons of southern New Mexico, where it probably attains its largest size (also in western Texas and Mexico). The wood is hard and heavy, but of little use, except for fuel as the trunks are generally much distorted, flattened, and twisted.

Description.—Leaves small, 1 to 1¾ inches long, ½ to 1 inch wide, ovate-heart-shaped, sharp pointed, margin sharply toothed; rough, with short bristly hairs above and below; leaf-stems and young shoots velvety. Fruit small, often sweet and pleasant. Bark much broken, except in young trees. Milky juice exudes from a freshwound.

PLATANACEÆ: PLANE-TREE FAMILY.

65.—Sycamore. (*Platanus Wrightii*, Watson.)

A middle sized tree, 40 to 60 feet in height and 1 to 2 feet in diameter, abundant in the mountain canyons of southwestern New Mexico, and in some localities being the predominant species (it occurs also in southeastern Arizona and in Mexico). The wood is light, soft, and brittle.

Description.—Leaves alternate, rounded in outline, 5 to 7 inches broad, deeply cut into 3 to 7 (chiefly 5) sharp-pointed lobes; usually a deep sinus at the base; young shoots and leaves densely clothed above and below with a velvety down, which is more or less persistent with age. The seeds are packed in a spherical head—"ball"—which is ¾ of an inch in diameter, 3 to 5 of these balls borne on a long pendent stem. The trunks are often crooked and more winding than other species of *Platanus*.

JUGLANDACEÆ: WALNUT FAMILY.

66.—WALNUT. (*Juglans rupestris*, Engelm.)

A tree of considerable economical importance, occurring quite abundantly in the rich soil of mountain canyons at elevations between 5,000 and 8,000 feet, ranging through southern New Mexico (Arizona and along the coast from southern to central California; eastward through western Texas); 30 to 60 feet in height and 1 to 2 feet in diameter. The wood is hard and heavy, but brittle, with a dark rich brown color, and nearly or quite as valuable for cabinet-work as that of the Black Walnut of the East.

Description.—Leaves compound, with from 5 to 10 pairs of leaflets, which vary in length from 2 to 3¾ inches by ¼ to 1 (chiefly ½ to ¾) inch wide; lance-shaped to somewhat broadly so, pointed or rounded at the base, and narrowing to a usually long thin point; margin finely toothed; young leaflets velvety, as are the buds, shoots, and leaf-stems; with age the former almost without the down, except on the veins. Fruit small, velvety when young, becoming more or less smooth at maturity; globular or slightly ovate; ½ to 1 inch in diameter, with a very thin husk; shell smooth, wrinkled; sweet and edible.

CUPULIFERÆ: OAK FAMILY.

67.—SCRUB OAK. (*Quercus undulata*, var. *Gambelii*, Engelm.)

Often a low shrub, or rather small tree, rarely more than 50 feet in height (exceptionally 75 feet) and 1½ feet in diameter, occurring abundantly on the eastern slopes of the Rocky Mountains of Colorado, in the high mountains of southern New Mexico and Arizona, where it probably attains its largest size. (It is also found in the Wahsatch Mountains of central Utah and in the mountains of western Texas.) The timber is heavy, hard, and strong, and rather tough when young, but it is important chiefly for fuel and tan-bark, as the large trees are too often hollow and defective for lumber.*

Description.—Leaves 1 to 5 (mostly 1 to 3) inches long, and ¾ to 3 inches wide, ovate (larger at upper end) or oblong in outline; margin with bristle-pointed coarse teeth, or rather deeply cut into from 3 to 5 somewhat equal lobes, with rounded ends; young shoots, leaf-stems, and under surface of leaves clothed with velvety yellowish down. Acorns, mostly solitary, sometimes in pairs, ovoid or oblong with sword-shaped point, ⅓ to ¾ of an inch in length, and ⅜ to ½ an inch in diameter, sometimes quite enveloped by the closely scaly and downy cup.† A variable variety, and for the present purpose no attempt is made to describe in any but general terms the many forms that probably belong here.

68.—BURR OAK. MOSSY-CUP OAK. OVER CUP OAK. (*Quercus macrocarpa*, Michx.)

One of the largest and most important timber trees, extending farthest west and northwest of any of the eastern Oaks. It is somewhat rare and much smaller as it occurs on the eastern foot-hills of the Rocky Mountains of Montana than in its more eastern range—central, north central, and northeastern States; here, being especially well developed on rich bottom-lands and prairies, sometimes reaching a height of 100 feet with a diameter of 4 to 6 feet. The wood is heavy, hard, and tough, and the most durable of any of our oaks. In its Rocky Mountain range it is scarcely of any economic importance, but eastward is extensively employed for carriage- and wagon-stock, agricultural implements, lumber, tie-timber, posts, etc.

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* It is a useful tree, furnishing desirable soil cover and shade for denuded hillsides.

† Trunk and branches often much twisted.

Description.—Leaves ovate, broader above or oblong in outline, tapering rather sharply at the base, 4 to 10 inches long, and 2 to 6 inches wide, more or less deeply lobed (3 to 6 pairs), the latter entire or with shallow blunt teeth or sub-divisions; young shoots minutely downy, as are the young leaves above and below, though usually becoming smooth on the upper surface at maturity. Acorns large, broadly ovate, solitary or in pairs (on strong footstalks an inch long), nearly or quite enveloped by a thick, scaly, mossy-fringed cup, together ¾ to 1¼ inches long and ¾ to 1 inch in diameter.

69.—"EVERGREEN OAK." "LIVE OAK." (*Quercus oblongifolia* Torrey.)

A small tree of little economic value, found along the foot-hills of the mountain ranges of southern Arizona and New Mexico (southward into Mexico; also on the foot-hills of the San Gabriel Mountains, southern California). Twenty to 40 feet high, and ½ to 2½ feet in diameter. The wood is very heavy and hard, but brittle; the largest trees are apt to be hollow, and hence seldom used except as fuel.

Description.—Leaves evergreen, leathery, 1 to 2 (exceptionally 3) inches long, and ½ to 1 inch wide, chiefly oblong, sometimes ovate-oblong, rounded or slightly heart-shaped at the base, rounded or pointed at the tip; margin entire or with a few shallow, distant, and usually sharp teeth; smooth above, minutely downy below, but less so in old leaves; young shoots and short leaf-stems velvety. Acorns sessile, or on very short stems, solitary or two to three together, ovate or oblong, ½ to ¾, sometimes 1 inch long; cups hemispherical, with tuberculate scales.

70.—WHITE OAK. (*Quercus grisea*, Liebmann.)

A tree 40 to 60 feet in height and 1 to 1½ feet in diameter, or a low shrub, ranging through the mountains of southern Colorado, southern New Mexico, at elevations between 5,000 and 10,000 feet (westward through southern Arizona to Colorado River, southern California, and southward through northern Mexico). Rather rare in parts of its range. The wood is exceedingly heavy, hard, and strong, but the large-sized trees are too often hollow and almost useless for timber.

Description.—A variable species presenting many forms, the position of which is difficult to determine; approximations to closely allied species are especially frequent in the shape and character of the leaves. Leaves ¾ to 2½ inches long, and ¼ to 1 inch wide, ovate, oblong, or narrowly elliptical in outline, rounded or somewhat heart-shaped at the base, pointed or rounded at the apex; margin entire, undulate-toothed to that with sharp or prickle-pointed teeth (var. *pungens*, Engelm.); young shoots and short leaf-stems downy, as is also the under surface of the leaves; mostly smooth above. Acorns sessile, or on short stems, oblong, ¾ to 1 inch long, and nearly ½ an inch in diameter; cups hemispherical, ½ inch broad; scales tuberculate.

71.—Black Oak. "Mountain Oak." (*Quercus Emoryi*, Torrey.)

A tree 40 to 50 feet in height and 1 to 3 feet in diameter, or a shrub at the eastern limit of its range; it occurs abundantly through the mountain ranges of southern New Mexico (eastern and southern Arizona, and western Texas) at elevations between 5,000 and 7,000 feet; rarely if ever found on hills or far from streams, preferring the fine gravelly or sandy soil of open canyons. The wood is very heavy and brittle, of a poor quality, and little esteemed, except for fuel, the large trees often becoming hollow or otherwise defective.

Description.—Leaves thick, ¾ to 2½ inches long, ½ to 1¼ inches wide, ovate, oblong-ovate, often approaching halberd-shape, with an acute point, and chiefly (sometimes rounded or with strongly) heart-shaped base; margin entire, but mostly wavy, with distant, shallow or rather large prickle-pointed teeth; mature leaves usually dark glossy green both sides; when young minutely downy, as are the young shoots and short leaf-stems, but the latter more densely so. Acorns mostly sessile—sometimes with short stem—ovate, with a rather sharp and prolonged point, ½ to ¾ of an inch long, and ⅜ of an inch in diameter; cup hemispherical, ½ inch broad, with close, smooth scales. Acorns abundant, sweet, edible. A tree with a scraggy appearance.

72.—(*Quercus hypoleuca*, Engelmann.)

A small but very handsome tree with evergreen foliage, found in the high mountain ranges of southwestern New Mexico, Santa Rita Mountains, southeastern Arizona (southward into Sonora, and in the Limpia Mountains of Texas), at elevations above 6,000 feet, usually preferring rocky or gravelly sites in deep canyons and valleys. Commonly 15 to 20, occasionally 50, feet in height, with a diameter of 2 feet; the trunks usually large for the height. The wood is heavy, very hard, and strong, but large-sized trees are often defective. In localities where it can be grown it would be a popular ornamental tree.

Description.—Leaves thick, commonly 2 to 3¼ inches long and ⅝ to 1 inch wide, lance-shaped, with rounded, slightly heart-shaped or acute base, the upper end usually tapering to a long thin point; margin *rolled down*, entire, or wavy, with few indistinct or shallow teeth—sometimes sharply toothed; young leaves downy above, always densely woolly below, but with age becoming smooth and dark green above; stems downy. Acorns usually sessile or sometimes with short stems, ovate, ½ to ⅝ of an inch long; cups hemispherical, with thin, downy scales. Trunk and branches generally gnarled and twisted.

73.—Canoe Birch. White Birch. Paper Birch. (*Betula papyrifera*.* Marshall.)

A rather large tree, growing chiefly in rich woodlands and along water-courses, and extending farther north than any other American deciduous tree. It has a limited range in the Rocky Mountains region, being found only in the Mullen Trail of the Bitter Root Mountains and in the region of Flathead Lake, Montana (eastward it ranges through the northern tier of States to the Atlantic coast, and far north of the United States boundary from the Atlantic to the Pacific). Sixty feet or more in height, with a trunk 2 to 3 feet in diameter. The wood is very close-grained, hard, and strong, being employed quite extensively in turnery, in the manufacture of paper-pulp, and for fuel. The tough durable bark separates readily into layers, and is often used for making canoes, etc.

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* See Dwarf Birch in list of shrubs, page 196.

Description.—Leaves, ovate to broadly ovate, 2 to 3½ inches long, 1½ to 2½ inches inches wide, with a rather long, narrow point, mostly abrupt or heart-shaped at the base (sometimes slightly wedge-shaped), smooth and dark green above, paler and with few hairs on the veins below. Seed small, with two thin wings, borne in a cylindrical scaly catkin 1 to 1½ inches long. Young branchlets often with numerous dots. Bark of the trunk chalky-white.

74.—BLACK BIRCH. "WESTERN POGUE-BIRCH." (*Betula occidentalis*, Hooker.)

Usually a small tree, 20 to 30 (exceptionally 60) feet in height and ½ to 1 foot in diameter, growing abundantly in moist soil of mountain canyons and along streams in the Rocky Mountains from northern New Mexico to Montana (also on the Pacific coast from the Sierra Nevadas of central California to Washington Territory and north of the boundary). It often forms dense thickets, a number of stems growing close together, and producing a useful local supply of straight timber for fencing, as well as for fuel. The wood is rather soft, but strong. The bark separates readily into layers, and is sometimes used for canoes.

Description.—Leaves generally quite small and thin, 1 to 1½ inches long and 1 to 1¼ inches wide, ovate-lance-shaped to broadly ovate—sometimes orbicular—with an acute, rounded, abrupt, or wedge-shaped base, and with a short or sometimes rather long point; margin cut (occasionally lobed) with glandular-pointed teeth; mostly smooth, or with few close hairs below; young leaves hairy; leaf stems slender, ½ inch long. Fertile catkins oblong or cylindrical, ¾ to 1 inch long, with hairy three-pointed scales (bracts); seeds with thin broad wing on two sides. Branches thickly dotted with resinous spots, especially on the recent wood. Bark close, dark to light brown; when newly parted, pale copper-yellow.

ALDERS.

75.—"WHITE ALDER." "CALIFORNIA ALDER." (*Alnus rhombifolia*, Nuttall.)

A small tree, seldom more than 30 feet in height and 1 foot in diameter, or reduced to a shrub. It is found in northern Idaho and along the valley of the Flathead River, northwestern Montana, growing mostly on the banks of streams (westward it ranges along the Pacific coast from southern California to British Columbia). The wood is light, soft, and brittle.

Description.—Leaves 1¼ to 3 inches long, ovate (sometimes broader above), or oblong-ovate, blunt or with sharp point, wedge-shaped at the base; margin with small teeth of two sizes; smooth (or nearly so) above, more or less downy on the under surface. Catkins bearing the seed (nutlets) oblong, ½ to ⅝ inch long; seeds small (1/12 of an inch long), ovate, very broad at upper end, and with a wing-like, thickened margin.

76.—*Alnus oblongifolia*, Torrey.

One of the largest deciduous trees of the southern Rocky Mountain region, growing abundantly on nearly all the mountain streams and very close to the water. It occurs in the ranges of southern Arizona, extending to New Mexico as far as the Rio Grande (southward into Mexico, and also in ranges of southern California). Forty to 60 feet, with a trunk from 2 to 3 feet in diameter. The wood is light, soft, and brittle, decaying rapidly, and of little value except for fuel.

Description.—Leaves commonly 1½ to 3½ inches long, and 1 to 2 inches wide (exceptionally 4 to 6 inches long), lance- to oblong-lance-shaped (sometimes ovate), apex acute or with a long narrow point; base wedge-shaped; margin (often rather coarsely) cut with glandular teeth of two sizes; slightly hairy below, especially on the veins, smooth above; leaf-stems ¼ to ½ inch long. Fertile catkins ovate-oblong, ½ to ¾ inch long; seeds (nutlets) ovate—very broad above, about 1/10 of an inch long, with a narrow wing-like margin. A handsome tree.

77.—SPECKLED ALDER. HOARY ALDER. BLACK ALDER. (*Alnus incana*, Willdenow.)

A shrub or small tree, 15 to 20 feet in height, with a slender trunk, seldom more than 3 to 6 inches in diameter. It occurs along watercourses and on the borders of swamps in the Rocky Mountain region, ranging from Colorado to Montana and northward (extending eastward to the Atlantic; also in Europe. A well-marked variety of this species (*virescens*, Watson) is found in the mountain ranges of the Pacific coast from southern California to British Columbia and northward). The wood is light and soft, and is used quite extensively for fuel in brickmaking.

Description.—Leaves 2 to 4 (exceptionally 5) inches long, and 1½ to 3½ inches wide, oval to broadly ovate, with rounded or heart-shaped base and more or less pointed apex; margin finely toothed, or with coarse teeth, which are themselves cut with smaller teeth; young leaves velvety on both sides, but with age becoming pale, and retaining the pubescence only (or chiefly) on the under surface (variety *virescens* has leaves smooth on both sides); leaf-stems and recent shoot rusty downy. Fertile catkins ovate, ½ to ⅞ inch long; fruit flat, orbicular, with thin margin mostly on two sides. Bark of brances reddish or grayish brown, with numerous light-colored dots.

SALICINEÆ: WILLOW FAMILY.*

78.—*Salix amygdaloides*, Anderson.

A small tree, found throughout the Rocky Mountain region on the banks of streams (also eastward through the northern United States);

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* See Willows, in list of shrubs, page 196.

10 to 30 feet high and 6 to 10 inches in diameter. The timber is soft, light, and weak.

Description.—Leaves lance-ovate, 2 to 4 inches long, ½ to 1 inch broad, margin finely and sharply toothed; pale or whitish beneath; footstalks (petioles) without glands.

79.—*Salix lasiandra*, Bentham.

An important willow for commercial purposes, several well-marked varieties of which having proved quite satisfactory osiers. Abundant on banks of streams in Rocky Mountains of Colorado and northern New Mexico (on the Pacific coast from central California to and north United States boundary). Generally more common and much larger tree than the preceding, although the wood is not materially different; in favorable localities it reaches a height of from 25 to 60 feet, with a diameter of 1½ feet or more.

Description.—Leaves 1 to sometimes 6½ inches long, lanceolate, with long thin point, finely and sharply toothed on the margin; smooth above, pale or whitish on the under surface; footstalks glandular at the upper end. The old bark is rather strongly furrowed, and is of a grayish or brownish color; the young branches are glossy yellow, and in habit not unlike the Weeping Willow.

80.—SAND-BAR WILLOW. (*Salix longifolia*, Muhlenberg.)

A small but widely-distributed species, occurring throughout the Rocky Mountain region (also in eastern United States and in the Pacific States). It is commonly found growing on the moist banks of streams and on sand-bars, in some cases forming thick growths. In the central Pacific coast region it is said to attain its greatest development, but it is a small tree, rarely more than 25 to 30 feet high and ½ to 1 foot in diameter. The wood is light and soft.

Description.—Leaves 3 to 4 inches long, $\frac{1}{12}$ to ½ (commonly $\frac{1}{6}$ to ¼) of an inch wide, linear to lance-shaped, long-pointed, tapering at the base, sessile or with short stems; margin entire, or with very small somewhat distant teeth.—Two or three varieties of this species occur, which differ from the type chiefly in the form of the leaves and pubescence.

81.—(*Salix flavescens*, Nuttall.)

A tree of 20 to 25 feet in height and 6 inches to 1 foot in diameter, found on the banks of streams in the mountains from New Mexico to Montana and Idaho (also occurring in central Pacific coast region.) It reaches its largest size in the southern Rocky Mountain region. The wood is light and lacking in strength; a variety of this species, called the Black Willow, and confined to the Pacific coast, has tough, strong wood.

Description.—Leaves 2 to 3 inches long, 1 to 1½ inches wide, ovate or lance-shaped, tapering at the base; with age becoming smooth and a dull green above, below whitish or with yellowish-brown pubescence.

POPLARS.

82.—QUAKING ASPEN OR ASP. AMERICAN ASPEN. (*Populus tremuloides*, Michaux.)

One of the most widely distributed of our forest trees, but of little value as a timber tree, yet of considerable importance for quickly covering mountain and hillsides denuded by fires, thus furnishing the necessary conditions for the growth of other longer-lived and better timber. Twenty-five to 50 feet in height, and 1½ feet or more in diameter. It is found abundantly throughout the Rocky Mountain region (northern United States, north of boundary, in south central and Pacific coast region,) at elevations between 6,000 and 10,000 feet. The wood is soft, light, weak, and little used except for light fuel and in the manufacture of paper-pulp; the poles occasionally for fencing.

Description.—Leaves 1 to 3 inches long, rounded-ovate, short-pointed, somewhat wedge or heart-shaped at the base; smooth on both sides, margin with fine teeth; footstalks slender and flattened at right angles to the plane of the leaf. The bark is chiefly smooth and of a grayish-white color.

83.—BALSAM POPLAR. BALM-OF-GILEAD. TACAMAHAC. (*Populus balsamifera*, Linn.)

A large tree occurring in the Rocky Mountains of Montana and Idaho (it also extends eastward through the Northern States and north of the United States boundary). It generally prefers and thrives best in moist situations along water-courses, often attaining a height of 60 to 80 feet, with a diameter of 3 to 6 feet. The wood is quite similar to that of the Big Cottonwood (*Populus monilifera*, Ait.), and a good substitute for it in more northern localities.

Description.—Leaves ovate, gradually tapering to a point, finely toothed on the margin, smooth above, whitish below. Branches round; large buds, coated with resinous gum, which is sometimes used in officinal preparations.

Variety *candicans*, Gray, of this species is found in Colorado, northward, and eastward, but is quite unknown in the wild state, being chiefly, if not entirely, introduced in the above range; very common. The wood is considerably heavier than that of the type.

Description.—Leaves usually larger, heart-shaped, *densely white beneath*, and with hairy footstalks.

84.—BLACK COTTONWOOD. "BITTER COTTONWOOD." (*Populus angustifolia*, James.)

Rather abundant throughout the Rocky Mountain region (also in southwestern Dakota and eastern Arizona); less common in southern part of its range, but one of the least valuable deciduous trees of the region. It grows in damp situations, along the borders of mountain streams, at elevations between 6,000 and 10,000 feet. A considerably smaller tree than the better known Big Cottonwood, seldom reaching a height of more than 30 or 50 feet, and 1½ feet in diameter. The timber is very light and soft.

Description.—Leaves smooth both sides, chiefly ovate-lance-shaped (sometimes narrowly lance-shaped), with a long tapering point, mostly rounded at the base, or sometimes tapering slightly at the base; margin with small rounded teeth. Branches round, with smooth bark.

85.—COTTONWOOD. CAROLINA POPLAR. BIG COTTONWOOD. NECKLACE POPLAR. (*Populus monilifera*, Aiton.)

The common cottonwood along the eastern base of the Rocky Mountains (and eastward to the Atlantic Coast). It is abundant on all the water-courses, and valuable chiefly for the rapidity of its growth. The timber is of little commercial importance, yet it is considerably used for cheap lumber, light fuel, and in the manufacture of paper-pulp; unless well protected, it decays rapidly when exposed to the weather. In western towns this tree is largely employed as a shade tree, as it reaches a desirable size in a comparatively short time, and is therefore often preferred to other trees. It grows to a height of over 100 feet, and 4 to 6 feet in diameter.

Description.—Leaves broadly triangle-shaped, somewhat heart-shaped or truncated at the base, long-pointed; margin with blunt incurved, hairy teeth. Young branches angled, but becoming round with age.

86.—COTTONWOOD. WHITE COTTONWOOD. (*Populus Fremontii*, Watson, var. *Wislizeni*, Watson.)

This species is found in southern Colorado, through New Mexico (western Texas, Arizona, southern California), and is the prevailing Cottonwood of the arid localities; rather abundant along streams in open country, but quite rare on precipitous sites. It is a large tree, commonly attaining a height of 50 to 80 feet, with a diameter of 3 to 4 feet. The wood is soft and light, but supplies the ordinary fuel of the region.

Description.—Leaves broadly triangle-shaped, sharp-pointed, somewhat wedge-shaped or truncate, and with more or less broad shallow sinuses at the base; margin with a few distant, blunt (occasionally incurved) teeth. Young bark yellowish, but becoming gray with age.

LILIACEÆ: LILY FAMILY.

[The plants belonging to this family are termed endogenous or inside growers, the woody stems being made up of a mingled mass of fibers, and not marked by annual rings as in the pines, maples, elms, etc.—exogenous or outside growers.]

87.—SPANISH BAYONET. (*Yucca elata*, Engelmann.)

A small tree, with a trunk usually not more than 10 to 15 feet in height and 4 to 7 inches in diameter. It is commonly met with in the dry gravelly soil of table-lands, ranging through western Texas, Arizona to Utah (probably in New Mexico), and southward into Mexico; wood light, soft, and brittle.

Description.—Leaves 1 to 2 feet long, very narrow, ⅜ of an inch or less wide, thick, stiff, terminating in a needle point; margin with a narrow white border and more or less with thread like filaments; base of the leaves much expanded, usually smooth. Flowers white, 1 to 2 inches long; fruit, a woody, oblong-ovate or cylindrical capsule 1½ to 2¾ inches long and 1¼ inches in diameter, obtuse at the base and beaked at the top; seeds rather large, *thin*, and *flat*, ⅜ to ½ inch wide.

88.—SPANISH BAYONET. MEXICAN BANANA. (*Yucca bacatta*, Torrey.)

Sometimes a tree 20 to 30 feet in height, with a trunk 1 foot or more in diameter, or at the northern limit of its range a stemless plant, bearing only a tuft of leaves. It occurs through New Mexico to southern Colorado (westward into southern California, southward into northern Mexico, and also in western Texas), in the latter range often forming quite extensive forests on the plains. The wood is of little economic value. The fiber of the leaves is strong, and when properly prepared by maceration is soft and pliable, furnishing an excellent material for making ropes, for which it is considerably employed, as well as by the Indians in making horse blankets and mats. Fruit sweetish, edible, and locally an important article of food.

Description.—The trunk is more or less set with dead leaves, which are broken down at the base. The mature loaves are thick, stiff, lanced-shaped, and from 1 to nearly 3 feet long, with a width of 1½ to 2 inches, broad at the base, narrowing, broadening again midway, and terminating in a long keen spine-point; margined with rather coarse threads, curved backward, usually rough or sometimes smooth, and concave above. The flowers are large and showy, 2 to 3 inches long; fruit hanging down, 2 to 4 (sometimes 5) inches long, ovate, oblong or cylindrical, usually with a beak; purple; seeds blackish, ⅛ to ⅜ inch broad, triangular, flattened on two sides.

The following species, omitted in the first edition, should be added as occurring in the Rocky Mountain region proper:

5*a*.—*Pinus monophylla*, Torr. and Fremont.

A small tree 15 to 20 feet high, found on dry slopes and mesas near Utah Lake, Utah (also in California and Arizona). Easily recognized by its single needles. Wood soft and weak; used for fuel. Edible seeds, used by the Indians.

25*a*.—*Juniperus Californica*, Carr., var. *Utahensis*, Engelm.

A small tree of 20 to 30 feet in height, with a diameter of 2 to 3 feet, often only a shrub. The common Juniper of central and southern Utah and Nevada, along the lower slopes and the western base of the Wahsatch Mountains (also in California and Arizona). Wood like No. 25.

28*a*.—*Ptelea trifoliata*, L.

(From the East to Mimbres River, N. Mexico.)

28*b*.—*Euonymus atropurpureus*, Jacq.

(Fort Union, Mont.)

41*a*.—*Acacia millefolium*.

Shrub or small tree, 10 feet high, Santa Rita Mountains, Arizona. Discovered by C. G. Pringle, in July, 1884, on foot hills.[1]

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[1] See Proc. Am. Acad. Arts and Sci., Vol. XXI, p. 427.

SHRUBS NOT BECOMING ARBORESCENT.

As far as known, the following list of shrubs comprises those that rarely, if ever, become arborescent; and the chief object in introducing them here is to complete, as far as possible, a full enumeration of the woody plants of the region. Plants woody only at the base have been mostly excluded. The annotations added may in some cases assist the reader in recognizing the species.

BERBERIDACEÆ: *Barberries.*

BERBERIS REPENS, Lindl. One foot or less in height: found throughout the Rocky Mountains, also on the Pacific coast; wood yellow.

BERBERIS FENDLERI, Gray. Three to 6 feet: southern Colorado and southward (westward to southern California).

ZYGOPHYLLACEÆ.

CREOSOTE-BUSH, *Larrea Mexicana*, Moric. Four to 10 feet: southern Colorado (to California; also in Texas): *strong-scented;* foliage *evergreen*, dense; flowers yellow; fruit beaked.

CELASTRACEÆ: *Staff-tree Family.*

PACHYSTIMA MYRSINITES, Raf. Low; Rocky Mountain region (northward and westward); foliage *evergreen*, forming dense clumps on timbered slopes.

RHAMNACEÆ: *Buckthorn Family.**

BUCKTHORNS:

Rhamnus alnifolia, L'Her. Two to 4 feet: Wyoming (westward and eastward). Fruit black, berry-like; 2 to 4 seeds (*nutlets*).

Rhamnus Californica, Esch. Southwestern Colorado and New Mexico (to California and northward to the valley of the upper Sacramento River). As it occurs in the Rocky Mountain region it is a low, spreading shrub (with young branches and under surface of the leaves white-woolly), but in California becoming a small tree 20 to 30 feet high: foliage evergreen; fruit black-purple, with scanty flesh and 2 to 3 seeds. (Introduced among the shrubs, because the Rocky Mountain form is never arborescent.)

NEW JERSEY TEA:

Ceanothus velutinus, Dougl. Two to 3 feet: Colorado, Utah (and northwestward): leaves thick, entire, resinous above; often velvety below. Var. *lævigatus*, (Torr. & Gray) with leaves mostly smooth below, is commoner than the species.

Ceanothus ovatus, Desf. Two to 3 feet: Colorado and Wyoming: leaves with small glandular teeth.

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* See arborescent species, page 168.

NEW JERSEY TEA—Continued.

Ceanothus sanguineus, Pursh. Four to 12 feet: on tributaries of Missouri River in Rocky Mountain region: *branches reddish.*

Ceanothus Fendleri, Gray. One to 2 feet: New Mexico to Colorado: branches grayish, spiny; leaves *small*, white-silky below.

VITACEÆ: *Vine Family.*

WILD GRAPE. *Vitis riparia*, Michx. Colorado (abundant in Atlantic region): leaves with 3 long-pointed lobes; fruit more or less with bloom.

VIRGINIA CREEPER. *Ampelopsis quinquefolia*, Michx. Colorado (and throughout eastern United States): fruit blackish; 5 leaflets, crimson in fall. "American Ivy. "Woodbine."

ANACARDIACEÆ: *Cashew Family.*

SMOOTH SUMACH. *Rhus glabra*, L. Three to 12 feet: Colorado, Utah, Idaho (eastward to the Atlantic): fruit in *dense mass* (*thyrse*), *crimson, hairy.*

POISON IVY. POISON OAK. *Rhus Toxicodendron*, L. Climbing: Colorado, Wyoming, Utah (eastward to Atlantic): 3 leaflets; fruit whitish; *poisonous to the touch.*

RHUS AROMATICA, Ait., var. *trilobata*, Gray. Two to 5 feet: abundant in Rock Mountain region (and westward): 3 leaflets; strong-scented.

ROSACEÆ: *Rose Family.*

MEADOW SWEET. *Spiræa betulifolia*, Pallas. One to 2 feet: head-waters of Misssouri River in Rocky Mountain region (westward to northern California and northward beyond the United States boundary; eastward to Alleghanies): flowers purplish; bark reddish. Var. *rosea* (Gray), has rose-colored flowers: Wyoming, Idaho (to Oregon and California).

NINE BARK. *Physocarpus opulifolia*, Maxim. Three to 10 feet: throughout the United States: flowers white, in flat clusters; bark grayish, loose, parting in layers.

PHYSOCARPUS TORREYI, Maxim. Lower and with leaves smaller than in the preceding: Colorado to Nevada, in the mountains.

CHAMÆBATIARIA MILLEFOLIUM, Maxim. Western Wyoming to California: flowers large, white; stout, much branched, *glandular-hairy.*

HOLODISCUS DISCOLOR, Maxim. Four feet or more: New Mexico, Colorado (and westward to Pacific), flowers white; hairy, spreading, and with gray-brown bark. Var. *dumosa* (Maxim.), 1 to 3 feet, with smaller leaves and less spreading.

SALMON BERRY. *Rubus Nutkanus*, Moçino. Three to 8 feet: Colorado to Montana (westward to the Pacific; eastward to northern Michigan): glandular-hairy; flowers large, white; fruit large, *red*, pleasant.

RUBUS DELICIOSUS, James. Three to 4 feet: Colorado: flowers very *large*, white; fruit large, purple, not agreeable.

WILD RED RASPBERRY. *Rubus strigosus*, Michx. Two to 3 feet: New Mexico to Montana (in Nevada; eastward through northern half of the United States) fruit *red*, pleasant; stiff-bristly; wood dying down every two years.

BLACK RASPBERRY. THIMBLE BERRY. *Rubus occidentalis*, L. Three to 8 feet: New Mexico to Wyoming (westward to the coast; eastward to Missouri, thence throughout Eastern States): stems with *keen, hooked prickles;* fruit blackish, pleasant.

PURSHIA TRIDENTATA, DC. Two to 5 (exceptionally 10) feet: Rocky Mountain region (and from Arizona to Southern California): spreading, much-branched, with gray or brown bark; young branches hairy; leaves *small*, crowded, wedge-shaped, 3- to 5-lobed, white-woolly below; upper surface of leaves with *sticky glands*; with pungent, balsamic odor; fruit velvety.

COLEOGYNE RAMOSISSIMA, Torr. Southern Colorado (to Nevada and Arizona); spiny, spreading, much-branched, bark grayish; leaves leathery and with delicate hairs; flowers yellow, conspicuous.

CLIFF ROSE. *Cowania Mexicana*, Don. One to 6 feet: New Mexico to Southern Colorado (also in northern Mexico and northern Utah): much-branched; bark whitish, stringy; flowers yellow; seed (akene) with tail 2 inches long.

EARLY WILD ROSE. *Rosa blanda*, Ait. One to 3 feet: Eastern Montana (and eastward through northern half of United States): with few delicate (or no) prickles; flowers pale rose-color.

ROSA SAYI, Schwein. One to 2 feet: common from Colorado to Montana (eastward to northern Wisconsin): thickly set with prickles; flowers solitary.

ROSA ARKANSANA, Porter. One to 6 feet: New Mexico to Montana (eastward to the Upper Mississippi): usually with closely-set prickles; flowers clustered.

ROSA NUTKANA, Presl. One to 4 feet: northern Utah to Montana (westward to Oregon and northward): thick stems with strong, straight to curve prickles; flowers single, 2 to 3 inches broad.

ROSA FENDLERI, Crepin. Four to 8 feet: New Mexico (western Texas, Sierras, California, and northward beyond United States boundary): with delicate straight or curved prickles; flowers *small*, single or clustered.

ROSA WOODSII, Lindl. One-fourth to 3 feet: Colorado (to Missouri) and northward through western Montana (and north of the United States boundary to the Saskatchewan), plains and valley: with delicate or curved prickles; flowers single or clustered, 1½ to 2 inches broad.

ROSA GYMNOCARPA, Nutt. Three to 10 feet: northwestern Montana and Idaho (also on the Pacific coast): prickles straight, delicate; flowers single or *few*.

JUNE BERRY. SERVICE BERRY. (*Amelanchier alnifolia*, Nutt.) Three to 8 feet: New Mexico to Montana westward to California; eastward to the Mississippi): smooth or woolly; flowers white, in cylindrical clusters; fruit ten-seeded, purple, edible.

PERAPHYLLUM RAMOSISSIMUM, Nutt. Four to 6 feet: southwestern Colorado (Utah, California, and Oregon): exceedingly branched; bark gray; flowers single or two to three together; light rose; fruit globe-like, edible.

SAXIFRAGACEÆ: *Saxifrage Family.*

MOCK ORANGE, SYRINGA. *Philadelphus microphyllus*, Gray. Southern Colorado and southward: flowers single, or two to three together; white, conspicuous.

JAMESIA AMERICANA, Torr. & Gray. Two to 3 feet: New Mexico, Colorado (and Utah): spreading, slim-branched shrub; branchlets hairy, as are the leaves below, but *whitish;* flowers in loose clusters.

FENDLERA RUPICOLA, Eng. & Gray. Southern Colorado and southward: erect, smooth, or hairy; flowers single, or two to three together; white.

WILD GOOSEBERRIES:

Ribes Leptanthum, Gray. One to 4 feet: Colorado, New Mexico (and in Sierras, California): branches stiff; thorns single or in threes, large; flowers yellow, one or two together; fruit smooth.

Ribes divericatum, Dougl., var. *irriguum*, Gray. Five to 12 feet: Colorado to Oregon: spreading; thorns single or in threes; flowers white, on 2- to 4-flowered stems; fruit smooth, dark purple, pleasant.

WILD GOOSEBERRIES—Continued.

Ribes oxicanthoides, L. One and one-half to 3 feet: Colorado to Montana (and north of the United States boundary; eastward through Northern States to the Atlantic): thorns single or in threes; flowers greenish; fruit purplish, small, smooth, pleasant; two to three berries on a stem.

Ribes rotundifolium, Michx. Northeastern Rocky Mountain region (and eastward to the Atlantic): fruit smooth, 1 to 3 berries on a stem.

Ribes Cynosbati, L. Two to 3 feet: sources of the Platte River, Colorado, Wyoming (and eastward through the Northern States): spiny; fruit large, *burr-like*, with *long* prickles; purple, edible.

Ribes lacustre, Poir. Rocky Mountain region (and westward to California; eastward through Northern States to Labrador): young stems *densely prickly;* fruit small, glandular-bristly, not pleasant. Variety *parvulum*, Gray, is smaller, nearly smooth, and commoner westward than the type. Swamps.

WILD CURRANTS:

Ribes prostratum, L'Her. Nearly recumbent: Colorado to Montana (and northward; also in Atlantic region): fruit *light-red*, glandular-bristly; gives off disagreeable odor when bruised, hence, "Fetid Currant."

Ribes Hudsonianum, Richards. Wyoming, Montana (and northward to Hudson's Bay): much like the preceding, but with white flowers and *dark-red smooth fruit.*

Ribes cereum, Dougl. New Mexico to (Washington Territory) Montana (and Dakota): minutely hairy and often gluey; flowers (calyx tube) *waxy-white;* fruit smooth, reddish, sweet. Variety *pedicellare*, Gray, has longer fruit-stems than the type: in Montana.

Ribes viscosissimum, Pursh. Idaho, Montana (and California): hairy, *glandular*, and *sticky;* fruit smooth, black.

Ribes floridum, L. Two to 3 feet: southeastern Colorado (and in the Great Lake and Atlantic regions): leaves with yellow resin-dots; fruit black, sweetish. "Wild Black Currant."

Ribes sanguineum, Pursh. Two to 12 feet (Colorado and California): sometimes white-woolly and glandular; flowers numerous, drooping, *rose-red;* fruit dark, tough, dry. Variety *variegatum*, Watson, small; flower clusters not drooping, *white.*

Ribes aureum, Pursh. Five to 12 feet: Colorado and northward (westward to the Pacific coast; common in cultivation eastward): flowers yellow, fragrant; fruit blackish. "Missouri Currant." "Buffalo Currant."

CORNACEÆ *Dogwood Family.*

DWARF CORNEL. *Cornus Canadensis*, L. Colorado and northward (eastward through northern United States): stems about half a foot, from a creeping trunk; flowers surrounded by four whitish leaves (involucre); fruit *bright red.*

RED-OSIER DOGWOOD. *Cornus stolonifera*, Michx. Two to 6 feet: same distribution as preceding; young shoots bright red; white flowers in flat clusters; fruit *white* to *lead-colored.*

CAPRIFOLIACEÆ: *Honeysuckle Family.*

RED-BERRIED ELDER. *Sambucus racemosa*, L. Three to 10 feet: "across the continent," in swamps: *pith* of *young shoots brown;* fruit *red.*

SAMBUCUS MELANOCARPA,* Gray. New Mexico to Montana (westward to Oregon and California): *pith* of *shoots brown;* flowers white; fruit black.

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* See arborescent species, No. 56, page 177.

COMMON ELDER. *Sambucus Canadensis*, L. Four to 10 feet: southern Rocky Mountain region (and eastward to the Atlantic from Canada to Florida): *pith of shoots pearl-white;* fruit blackish with some bloom.

"HIGH-BUSH CRANBERRY." *Viburnum pauciflorum*, Pylaie. Two to 5 feet: Colorado and northward (eastward in northern regions): smooth or hairy; fruit clustered, globular, *red, acid,* edible, flat-seeded. In cold situations.

"WOLF-BERRY." *Symphoricarpos occidentalis*, Hook. Colorado and Montana (northward and eastward): low, stout; flowers small, white to pinkish, *hairy* inside; *fruit white.*

SNOWBERRY. *Symphoricarpos racemosus*, Michx. "Across the continent" (common generally in cultivation): slender; flowers smaller and less hairy than in preceding species; fruit *large, white.* Variety *pauciflorus*, Robbins, low, more spreading, with few flowers: in mountains of Colorado (to Oregon, Vermont, and northward).

SYMPHORICARPOS OREOPHILUS, Gray. Mountains of Colorado (Utah and Arizona, to California and Oregon): flowers ¼ to ½ inch long, much larger than in preceding species.

HONEYSUCKLES (*Two to three flowers in the axils of the leaves*):

Lonicera Utahensis, Watson. Mountains of Montana (Utah, Oregon, and northward): erect; flowers ⅔ of an inch long, straw-colored; berries red.

Lonicera involucrata, Banks. Mountains of Colorado (and California to Alaska; eastward into Canada): erect, 2 to 10 feet; flowers yellow with sticky hairs; two blackish or purple berries—often joined.

Lonicera ciliosa, Poir. Mountains of Montana; northward and southward to Arizona and California: twining; one or two pairs of the topmost leaves joined into one piece; flowers yellow to crimson; berries orange to red.

COMPOSITÆ: *Composite family* (Sunflowers, Thistles, Etc).

THOROUGHWORT. *Eupatorium ageratifolium*, D C. Three to 7 feet: southern Colorado to Texas: branches chiefly herbaceous.

GROUNDSEL-TREE. *Baccharis salicina*, Torr. and Gray. Three to 12 feet; Colorado to Texas: sticky, with resinous exudation.

TETRADYMIA CANESCENS, D C. Northern Wyoming to New Mexico (also in Arizona, California, and British Columbia): clothed with a close *persistent white wool;* leaves *narrow*, 1 inch long; flowers yellow; branches *close* and upright. Variety *inermis*, Gray, has shorter leaves and closer branches; more common than the type.—Under 2 feet, as are the following.

TETRADYMIA GLABRATA, Gray. Colorado (and from Utah to California and Oregon): clothed with a white loose wool, which is not persistent; branches spreading; leaves ½ inch long; flowers yellow.

TETRADYMIA NUTTALLII, Torr. and Gray. Wyoming and Utah: *white* with a *persistent wool* and armed with *stiff spines*; branches short and close; flowers yellow.

TETRADYMIA SPINOSA, Hook. and Arn. Two to 4 feet: southern Wyoming to Arizona (also in southeastern California and eastern Oregon): branches spreading widely, densely white-woolly, and with curved or straight spines.

ERICACEÆ: *Heath Family.*

BLUE BERRIES:

Vaccinium occidentale, Gray. One foot or more: Uintah Mountains, northeastern Utah (and in Sierra Nevadas, California): leaves bluish; berries small, blue-black, with bloom.

BLUE BERRIES—Continued.

Vaccinium caespitosum, Michx. Less than ½ foot: Rocky Mountains from Colorado northward (to Alaska, and eastward in Labrador, and the White Mountains, New Hampshire; growing in tufts: berries rather large, blue (bloom), sweet. Variety, *cuneifolium*, Nutt, is ½ to 1 foot: mountains of Colorado (to California, British Columbia, and Lake Superior).

Vaccinium Myrtillus, L. One foot or less: Colorado, Utah, and northward (to Alaska): branches *angled, green;* berries black.—"Whortleberry," "Bilberry." Variety *microphyllum*, Hook., 3 to 6 inches, with leaves ⅙ to ⅓ of an inch long, and berries reddish at first.

"BEARBERRY." "KINNIKINNICK." *Arctostaphylos Uva-ursi*, Spreng. New Mexico (to California, to New Jersey), and northward: creeping; foliage *thick, evergreen; berries red.*

WINTERGREEN. *Gaultheria Myrsinites*, Hook. Colorado and Utah to Montana (northward and westward): procumbent, tufted; foliage *evergreen*, with aromatic flavor; berries scarlet.

BRYANTHUS EMPETRIFORMIS, Gray. One-half a foot or more: western Wyoming, Montana, (and northward): leaves *crowded, evergreen;* flowers, rose-colored.

PALE LAUREL. *Kalmia glauca*, Ait. One to 2 feet: Colorado and northward in the Rocky Mountains (eastward through the northern United States): cold bogs; branchlets two-edged; leaves *evergreen*, white beneath, margin rolled; flowers large, lilac-purple.

LABRADOR TEA. *Ledum glandulosum*, Nutt. Two to 6 feet: northern Idaho and western Montana (also in the Pacific region and British America): leaves 1 to 2 inches long, persistent, with resinous dots below, fragrant when bruised; flowers white.

OLEACEÆ: *Olive Family.**

FORESTIERA NEO-MEXICANA, Gray. Six to 10 feet: southern Colorado to New Mexico (also in Texas): branches warty; leaves 1 inch long; flowers inconspicuous; fruit dark, cherry-like.

CHENOPODIACEÆ: *Goosefoot Family.*

GREASEWOOD. *Sarcobatus vermiculatus*, Torr. Two to 8 feet: southern Wyoming and southward (also in the Great Basin to the Upper Missouri): spreading, scraggy; branches stiff, with white bark; leaves *narrow*. Most abundant of the shrubs called "Greasewood."

ELAEAGACEÆ: *Oleaster Family.*

ELAEAGNUS ARGENTEA, Pursh. Six to 12 feet: Utah to Dakota (and eastward to Canada): young branches with *rusty scales;* flowers yellowish inside, fragrant; fruit cherry-like, mealy, edible, with an eight-grooved stone.

BUFFALO BERRY. *Shepherdia argentea*, Nutt. Five to 18 feet: in the mountains from Mexico to Montana (and northward to the Saskatchewan River, British America; westward to the Pacific coast ranges): spiny; leaves *silvery;* berries scarlet, almost stemless, acid, edible, with flat shiny seed.

CANADIAN SHEPHERDIA. *Shepherdia Canadensis*, Nutt. Three to 6 feet: in the mountains from New Mexico to southern Montana (also ranging eastward from the Columbia River to the Atlantic): young branches, leaves, and yellowish flowers *rusty-scaly;* berries yellowish, red, tasteless.

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* See arborescent species, page 177.

CUPULIFERÆ: *Oak Family.*

DWARF BIRCH. *Betula glandulosa,** Michx. One to 6 feet: Rocky Mountain region (and northern—latitude 40°—California to Washington Territory; eastward through the Northern States to the Atlantic, and north of the United States boundary): peculiar for its *small, rounded leaves,* and *resinous, glandular spots* on the young branches.

BEAKED HAZEL-NUT. *Corylus rostrata,* Ait. Two to 5 feet: Colorado to Montana (westward to Washington Territory, northward and eastward to the Alleghenies): hard-shelled nut inclosed by a leafy cup, which terminates in a beak.

SALICINEÆ: *Willow Family.*†

WILLOWS:

Salix cordata, Muhl.; var. *Mackenziana,* Hook.; var. *vestita,* Anders. "Diamond Willow." Ranging through the northern part of the United States from the Atlantic to the Pacific and northward to the Arctic coast.

Salix Novæ-Angliæ, Anders.; var. *pseudomyrsinites,* one to 3 feet; var. *pseudocordata,* Anders., not tall: mountains of Colorado and Montana (northward to the Saskatchewan and Mackenzie Rivers).

Salix irrorata, Anders. Six to 8 feet: central Colorado (mountains near Golden, Manitou, and Empire City): leaves 3 to 4 inches long, ½ inch or less wide; year-old twigs white with bloom.

Salix monticola, Bebb. Eight to 12 feet: central Colorado (Golden, Georgetown, Empire City), marshy situations in the mountains: very dense shrub; leaves 3 to 6 inches long, 1 to nearly 2 inches wide.

Salix rostrata, Richards. Northern Idaho and Montana (to Vancouver Island, northward to the Saskatchewan, eastward to New England): with somewhat the habit of low bushy tree.

Salix chlorophylla, Anders. One and one-half to 6 feet: Rocky Mountains (and northward to the Saskatchewan; also in the Wahsatch Mountains, central Utah, and in the Cascade Mountains, Oregon, and Washington Territory), at an altitude of 11,000 feet: straggling, year-old twigs shiny chestnut. "Green Willow."

Salix candida, Willd. Rare; 2 to 5 feet: bogs and foot-hills of the Rocky Mountains; noted near Cutbank Creek, Montana, and in Colorado: young shoots with white wool; older twigs shiny red; leaves 2 to 4 inches long, ½ to ¾ inch wide.

Salix glauca, L., var. *villosa,* Anders. Three to 7 feet: low meadow and foot-hills of the Rocky Mountains: a spreading shrub, with leaves 2 to 4 inches long and entire margin.

Salix desertorum, Richards. One to 2 feet; leaves 1 inch long and less than ¼ inch wide, white-woolly beneath, with a prominent yellow midrib (in variety *Wolfii* the leaves finally become smooth, and are nearly the same color on both sides): a scraggy shrub, forming clumps on mountain slopes of the Rockies considerably above the timber line.

Salix arctica, R. Br.: var. *petræa,* Anders. Colorado, (California, and far northward): creeping, the half-buried branches sending up twigs 2 to 3 inches long.

Salix vestita, Pursh. Old Marias Pass, northern Montana, at altitudes of 6,000 to 8,000 feet (also in Canada and Labrador): procumbent, sending up branches 2 to 3 feet high, and forming massy growths in rocky places sometimes 10 feet in diameter.

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* See arborescent species, Nos. 73, 74, pages 183, 184.

† See arborescent species, Nos. 78 to 81, page 185.

WILLOWS—Continued.

Salix reticulata, L. In the Rocky Mountains (and northward to the Arctic coast): a dwarfed species with twisted and buried stems, the leaves rising only a few inches above the ground.

CONIFERÆ: *Pine Family.*

COMMON JUNIPER. *Juniperus communis*,* L. Four to 10 feet (or with care and cultivation occasionally becoming arborescent): in the Rocky Mountains from New Mexico to Montana (eastward through the Northern States and northward throughout British America; native also in Europe). With somewhat erect and spreading branches; leaves in threes, ⅓ to ¾ of an inch long, narrow, needle-pointed, whitish and concave above: berries ¼ of an inch in diameter, *densely white with bloom.* Bark of branches with ridged scales. Variety *Alpina*, Linn., differs from the type in being quite or nearly prostrate, forming mat-like growths with its widely extended branches; leaves ¼ to ⅜ of an inch long, broader, curved, and less spreading: chiefly northern in the Rocky Mountains and eastern United States. Considerably used as an ornamental shrub.

CREEPING JUNIPER. *Juniperus Sabina*, L., var. *procumbens*, Pursh. Abundant in the mountains from Colorado to Montana (westward to the Pacific coast eastward through the Northern States to the Atlantic, and north of the United States boundary): a prostrate shrub of considerable importance in the forest economy of the region, as by its abundance it retains the snow, and thus preserves a much-needed supply of water in mountain streams. Foliage dense; prostrate branches taking root; often scaly with persistent dead leaves; berries ¼ to ⅓ of an inch in diameter.

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* See arborescent Junipers, Nos. 24, 25, 26, page 166.

THE FORESTS OF LOS ANGELES, SAN DIEGO, AND SAN BERNARDINO COUNTIES, CALIFORNIA.[1]

By ABBOT KINNEY, California.

The term "forest," as it is understood in the older States, is applicable in only a limited extent to the natural tree and brush growths of southern California.

Upon the mountain heights alone would the Eastern man feel himself to be in a forest. No account of the forests of southern California would, however, be complete without a description of all the natural tree and brush growths found here.

As has been said, there are no forests, properly speaking, in the valleys or on the plains. The growths in these portions of the country consist of the following: On the plains, near the sea, and near rivers or damp swampy places, Willows grow in rank dense groves, and furnish a large amount of fire-wood. The Sycamore strays down the canyons and water-courses to within sound of the ocean breakers. It is only used for fire-wood.

In the valleys large groves of Oak occur; these trees are from 20 to 40 feet apart, and are often magnificent old monarchs, most picturesque and attractive. *Quercus lobata*, or the White Live-Oak, forms the larger part of the groves, but the Red Oaks, *Quercus chrysolepis*, and *Quercus agrifolia*, with their dark-green, glistening, holly-like leaves, are the most attractive. These are scattered through the groves and canyons. The oak groves resemble the plantations of the most beautiful

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[1] This short report by Mr. Abbot Kinney, now chairman of the California State Board of Forestry, was prepared for this Division in the spring of 1886, in the hope that by aiding such work the then incipient forestry interests of California might be fostered. It has been printed in the report of the California Board of Forestry, and is here produced because it serves to show how even the preservation and protection of natural brush lands may become a subject of solicitude on the part of States and communities.

English parks. The magnificent trees spread a generous shade over the fields of wild flowers and grasses. Grain is often planted under the oaks and matures well, only a little later than that in the open plains.

It is a great regret to every lover of nature to see such characteristic beauty, so difficult to recreate, rapidly disappearing. The broader canyons, when there is enough good soil, are enchanting.

As we leave the sea, the water-courses, or more properly flood-courses, of the country are covered by Cottonwood trees (*Populus Fremontii* and *Populus trichocarpa*). These, like the Oaks, frequently form beautiful parks on the damp lands where they grow. One of the handsomest of these groves is at San Jacinto, in San Diego County.

In the great Colorado Desert and on its edges are found several useful stunted trees that form in favorable locations considerable plantations. These are the Iron-Wood, Mesquite, the Screw-Bean, and the Piñon Pines. The last three bear edible fruit, which is collected by and forms the main support of the desert Indians.

In the Mojave Desert a tree cactus grows which is being made into paper, on a large scale, by an English company. This is the *Yucca brevifolia*. It grows about 20 to 30 feet high, and forms the same grove-like plantations so frequent in this dry country. In the mountain canyons opening on the desert side grow the striking California Palms, *Washingtonia filifera*.

The edible Oak acorns, the nut of the California Walnut, and the fruit of the desert trees spoken of form important possible sources of food.

Speaking generally, it must be borne in mind that the plains and deserts of southern California are devoid of trees, and when trees do occur they never form forests.

In the lower mountain canyons, wherever there is water, the growths are dense. The principal trees are the Willow, Alder, Maple, and Mountain Live Oak (*Quercus oblongifolia*). These are mixed with trees coming up from the valleys on the one side, principally Oaks, and down from the mountain heights on the other, principally Spruce (*Abies Douglasii*). The whole is inextricably tangled up with dense chaparral and charmingly ornamented with large fern-brake.

The deciduous trees of the country are almost exclusively confined to the canyons or the damp land below them, or to the courses of the waters. The *Quercus oblongifolia* is the only one of our Oaks valuable for timber.

On the mountains the real forest is found. Considerable quantities of valuable timber exist on the Sierra Madre, San Bernardino, San Jacinto, and Cuyamaca Mountains. The Sierra Madre range has been too steep and inaccessible as yet to be exploited; but on San Bernardino and San Jacinto large saw-mills are continually at work, supplying the colonies below in the valleys with lumber, but furnishing none for export.

The principal timber cut is Pine. Spruce and Cedar are also cut and sold; the latter largely split for posts. The most important trees in the mountains are:

Pinus Lambertiana, Sugar Pine.
Pinus ponderosa, Pitch Pine.
Pinus Coulteri, Nut Pine.
Pinus Sabiniana, Digger Pine.
Pinus Jeffreyi, Yellow or Bull Pine.
Pseudotsuga Douglasii, Spruce.
Juniperus Californica, Juniper.
Libocedrus decurrens, White Cedar.
Abies concolor, Silver Fir.
Quercus chrysolepis, Red Live Oak.
Quercus Kelloggii, White Oak.

The timber is said by the lumbermen to be softer and less valuable than that farther north. The low foot-hills near the coast are generally devoid of trees or shrubs. Those on the desert are absolutely bare. With these exceptions, all the foot-hills and mountains not covered with trees are more or less thickened with evergreen bushes, called, collectively, chaparral. These grow from 3 to 15 feet in height and are frequently almost impenetrable. This chaparral is composed principally of Scrub Oaks, Manzanita, Wild Lilac, Grease-wood, and Sumac. On the lower foot-hills this brush is cut and grubbed up for fire-wood. In the mountains and canyons it furnishes food for the bees, and, most important of all, it acts as a reservoir, in allowing the rains of the wet season time to seep into the soil and rock veins, to appear again in the dry season as springs in the low country. This brush, together with the trees, also protects the country from the formation of destructive torrents and floods, and modifies the desert winds, which are already somewhat detrimental, at times, to vegetation.

These brush lands almost all belong to the Government, and, being of little direct value, will probably long remain its property. Every year disastrous fires sweep off great areas of this mountain covering. The Government sets no watch and takes no heed of its property, and the fires run into and destroy the timber as well as the brush. Every year, as a consequence, water-rights are decreased in value, through the springs diminishing in summer, and torrents run more violently and bring down more sand and stones to scatter on the farms. The floods each wet year are more destructive than before. Lately, floods have swept away twenty-two houses in Los Angeles, and interrupted travel for weeks on the Southern Pacific Railroad, in the Soledad Canyon, and for months on the California Southern road, in the Temecula Canyon. On each of these water-sheds extensive destruction of trees and brush had taken place in the Soledad by deliberately set and deliberately repeated fires.

It is very important that steps should be taken to preserve these mountain coverings, so as to maintain the tax-paying power of the community, which can not exist here if the springs become dry.

For the forest maps of these counties, comprising an empire of land, I am indebted, for Los Angeles, to Mr. George E. Jackson, and, for San Diego, to Mr. T. E. Vandyke and Mr. M. G. Wheeler.

Cupressus macrocarpa and *Guadalupensis* are not found in Los Angeles County, to my knowledge, in a state of nature. Some of the Sumacs, as the one with edible berries, do not extend to us.

The *Pinus Torreyana* is confined to one little nook of San Diego County. On the other hand, the *Yucca brevifolia*, or tree cactus, seems not to be known in San Diego County, and the beautiful fragrant Bay tree does not extend south of the Los Angeles canyons.

In the second Sierra Madre range of Los Angeles County there are about two hundred Redwood trees, *Sequoia sempervirens*—a fact not generally known, owing, doubtless, to the inaccessible character of the mountains where they are.

In this connection it is proper to call attention to the considerable number of trees and shrubs perpetuated in California that have long become extinct elsewhere. One may well think it probable that the mild and equable climate where this has happened may be as favorable to man as it has been to vegetable growth.

The necessity of the hour is the intelligent supervision of the forests and brush lands of California, with a view to their preservation. The cutting and use of the forests should be so reasonably regulated as to insure their reproductive power, and above all, maintain the forest influence on the climate and secure to the farmer the perennial character of the springs and streams necessary in the dry season for irrigation; also to protect the low lands against floods and torrents that occur here whenever the mountains are denuded.

TREES AND SHRUBS OF SAN DIEGO COUNTY, CALIFORNIA.

[The following list is a modification of that in the first edition of this report. That list was compiled mainly from Watson's Botany of California. The modifications have been made upon the authority of Mr. C. R. Orcutt and Dr. S. B. Parish, both of San Diego, County, Cal. Thanks are especially due to Dr. Parish, who is writing a flora of this region, for the addition of several unpublished species. The Cacti, and other plants not truly shrubs or trees, have been omitted. A few species, however, not always woody throughout, have been inserted. The fact that Mr. Kinney submitted a list confined to San Diego County must explain the insertion of such a limited list, while it would have been desirable to embrace the flora of Los Angeles and San Bernardino Counties as forming a true botanical region.—B. E. F.]

ACANTHACEÆ: Acanthus family.
    Beloperone Californica, Benth.
ANACARDIACEÆ: Cashew family.
    Rhus diversiloba, Torr. & Gray. "Poison Oak;" climbing.
    Rhus aromatica, Ait., var. *trilobata*, Gray. Two to 5 feet.
    Rhus integrifolia, Benth. & Hook. Five to 10 feet; evergreen.
    Rhus laurina, Nutt. Large shrub, with evergreen foliage.

BATIDEÆ:

Batis maritima, Linn. Sea-side shrub, 3 to 4 feet, generally prostrate.

BERBERIDACEÆ: Barberries.

Berberis repens,[1] Lindl. Less than 1 foot high.

Berberis pinnata, Lag. Two to 6 feet high.

Berberis Neviniana,[2] Trelease.

BIGNONIACEÆ: Bignonia family.

Chilopsis saligna,[3] Don. Shrub, or small tree, 10 to 20 feet high.

BUXACEÆ:

Simmondsia Californica, Nutt. Low shrub.

CAPPARIDACEÆ: Caper family.

Isomeria arborea, Nutt. Three to 5 feet high.

CAPRIFOLIACEÆ: Honeysuckle family.

Sambucus glauca,[4] Nutt. Elder. Shrub or small tree.

Symphoricarpos racemosus, Michx. Snowberry. Two to 4 feet.

Lonicera hispidula, Dougl. Honeysuckle. More or less twining.

CELASTRACEÆ: Staff-tree family.

Euonymus Parishii,[2] Trelease.

Euonymus occidentalis,[5] Nutt.

CHENOPODIACEÆ: Goosefoot family.

Atriplex hymenelytra, Watson. Two to 3 feet.

Atriplex canescens, Watson. Under 2 feet.

Grayia polygaloides, Hook. & Arn. One to 3 feet.

Sarcobatus vermiculatus,[6] Torr. Two to 8 feet high; commonest of the "Greasewoods," and very probably occurs in this range.

COMPOSITÆ: Composite family.

Acamptopappus sphærocephalus, Gray. One to 3 feet.

Aplopappus Palmeri, Gray.

Aplopappus pinifolius, Gray. Two to 4 feet.

Peucephyllum Schottii, Gray. Under 1 foot.

Baccharis glutinosa, Pers.

Baccharis Emoryi, Gray.

Baccharis sergiloides, Gray.

Baccharis sarothroides, Gray.

Bigelovia teretifolia, Gray. Low shrub.

Bigelovia paniculata, Gray.

Artemisia tridentata, Nutt., var. *angustifolia* Gray.

Tetradymia canescens, D C. One to 2 feet high.

CONIFERÆ: Pine family.[7]

Juniperus Californica, Carr. A shrub or small tree, sometimes 20 to 30 feet.

Libocedrus decurrens, Torr. One hundred to 150 feet high.

Pseudotsuga Douglasii, Carr., var. *macrocarpa*. A rather large tree 40 to 50 feet or more in height, probably occurring in this range.

Pinus Lambertiana, Dougl. "Sugar Pine." A very large tree, sometimes 300 feet.

Pinus Parryana, Engelm. Twenty to 30 feet high; probably occurs in this range.

Pinus Torreyana, Parry. Twenty to 30 feet high.

Pinus ponderosa, Dougl. "Yellow Pine." One of the largest pines, sometimes 150 to 300 feet high.

Pinus Jeffreyi, Murray. "Bull Pine." One hundred feet high.

Pinus Murrayana, Balf.

Pinus Sabiniana, Dougl. "Nut Pine," "Digger Pine." Sixty to 100 feet high.

Pinus Coulteri, Don. Sixty to 100 feet or more in height.

Pinus tuberculata, Gord.

Abies concolor, Lindl. & Gord.

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[1] Collected in San Diego County, by Dr. E. Palmer, in 1875.

[2] Unpublished.

[3] See No. 61, p. 179.

[4] See No. 56, p. 177.

[5] C. R. Orcutt, in First Biennial Report, California Forestry Board.

[6] Specimens collected in San Luis Valley in 1873 by John Wolf.

[7] See Coniferæ, p. 159.

CORNACEÆ: Dogwood family.

Cornus Californica, C. A. Meyer. Six to 15 feet.

Cornus pubescens, Nutt. Four to 10 feet.

Garrya flavescens, Watson, var. *Palmeri*, Watson. Four to 8 feet; evergreen.

CUPULIFERÆ: Oak family.

Quercus undulata, Torr., var. *pungens*, Engelm. A shrub under 8 feet.

Quercus dumosa, Nutt. A slender shrub or small tree 20 feet high.

Quercus oblongifolia,[1] Torr. Twenty to 30 feet high.

Quercus chrysolepis, Liebm. "California Live Oak." At high elevations a shrub, but elsewhere generally a large tree.

Quercus Palmeri, Engelm. A shrub 8 to 10 feet high.

Quercus agrifolia, Née. "Encino." A large tree. Variety *frutescens* is a shrub under 5 feet.

Quercus Kelloggii, Newberry. Shrub or middle-sized tree.

Castanopsis chrysophylla, A. D C. Western Chinquapin. A large shrub or small tree; found only sparingly.

Alnus rhombifolia, Nutt. A rather large tree known as "White Alder," "California Alder."

Alnus oblongifolia, Torr. A small tree 20 to 30 feet high.

ERICACEÆ: Heath family.

Arctostaphylos pungens, H. B. K. Manzanita. Procumbent or rising 8 to 10 feet.

Arctostaphylos glauca, Lindl. Great-berried Manzanita. Eight to 20 feet, and often 1 foot in diameter at the base.

Arctostaphylos bicolor, Gray. Manzanita. Three to 4 feet high.

Arctostaphylos Prylei,[2] Parry.

Arctostaphylos arguta, Zucc., var. *diversifolia*, Parry.

Rhododendron occidentale, Gray. Azalea. Two to 6 feet high.

EUPHORBIACEÆ: Spurge family.

Bernardia myricæfolia, Watson. Three to 10 feet.

Acalypha Californica, Benth. Shrub.

Euphorbia misera, Benth. Two to 3 feet high.

GNETACEÆ.

Ephedra Californica, Watson. Mostly decumbent.

Ephedra trifurca, Torr.

HYDROPHYLLACEÆ: Water-leaf family.

Eriodictyon tomentosum, Benth. Six to 10 feet.

Eriodictyon glutinosum, Benth. Three to 5 feet.

JUGLANDACEÆ: Walnut family.

Juglans Californica, Watson. California Walnut. A shrub or tree sometimes 60 feet high; occurs only sparingly in this range; cultivated.

LABIATÆ: Mint family.

Hyptis Emoryi, Torr. Four to 5 feet.

Audibertia stachyoides, Benth.

Audibertia Palmeri, Gray.

Audibertia Clevelandi, Gray.

LAURACEÆ: Laurel family.

Umbellularia Californica, Nutt. "Mountain Laurel," "Spice Tree." Shrub or tree 10 to 70 feet.

LEGUMINOSÆ: Pulse family.

Pickeringia montana, Nutt. Four to 7 feet high.

Amorpha Californica, Nutt. Three to 8 feet.

Dalea Parryi, Torr. & Gray.

Dalea Emoryi, Gray.

Dalea Californica, Watson.

Dalea Schottii, Torr.

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[1] See No. 69, p. 182.

[2] Unpublished.

LEGUMINOSÆ: Pulse family—Continued.
Dalea spinosa, Gray. Four to 15 feet.
Olneya Tesota, Gray. "Iron-Wood." Small tree 15 to 20 feet high.
Cercis occidentalis, Torr. Red-Bud, Judas tree. Small tree 10 to 15 feet high.
Parkinsonia Torreyana, Watson. "Palo Verde." A tree 20 to 30 feet high.
Prosopsi juliflora,[1] D C. "Honey Mesquit." A tree 30 to 40 feet high.
Prosopis pubescens,[1] Benth. "Screw-Pod Mesquit." A tree 15 to 30 feet high.
Acacia Greggii,[1] Gray. Cat's Claw. Small tree 10 to 20 feet high.
Calliandra eriophylla, Benth.

LILIACEÆ: Lily family.
Nolina Parryi, Watson.
Nolina Bigelovii, Watson.
Yucca baccata,[2] Torr. "Spanish Bayonet." "Mexican Banana." Sometimes 20 feet.

MALVACEÆ: Mallow family.
Malvastrum Thurberi, Gray. Woody base.

OLEACEÆ: Olive family.
Fraxinus dipetala, Hook. & Arn. Small tree.
Forestiera Neo-Mexicana, Gray.

PALMÆ: Palm family.
Washingtonia filifera, Wendl. Twenty to 40 feet high and 2 to 3 feet in diameter.

PAPAVERACEÆ: Poppy family.
Romneya Coulteri, Harv. Four to 15 feet.
Dendromicon rigidum, Benth. Two to 8 feet high.

PLATANACEÆ: Plane-tree family.
Platanus racemosa, Nutt. "Buttonwood." Sycamore. Large tree, often 100 feet.

POLYGALACEÆ: Milkwort family.
Krameria parvifolia, Benth. One to 2 feet high.
Krameria canescens, Gray. One to 2 feet high.

POLEMONIACEÆ: Polemonium family.
Gilia Californica, Benth. Shrub 2 to 3 feet high.
Gilia pungens, Benth., var. *Hookeri*, Gray. Low shrub.

RHAMNACEÆ: Buckthorn family.
Zizyphus Parryi, Torr. Four to 15 feet high.
Zizyphus lycioides, var. *canescens*, Gray.
Condalia spathulata, Gray.
Rhamnus, crocea, Nutt. Three to 15 feet high.
Rhamnus crocea, Nutt., var. *pilosa*,[3] Trelease.
Rhamnus Californica, Esch. Four to 18 feet high; var. *tomentella* more southern.
Adolphia Californica, Watson. Two feet high.
Ceanothus thyrsiflorus, Esch.
Ceanothus sorediatus, Hook. & Arn.
Ceanothus cordulatus, Kellogg.
Ceanothus divaricatus, Nutt.
Ceanothus integerrimus, Hook. & Arn. Two to 3 feet high.
Ceanothus crassifolius, Torr. Four to 12 feet high.
Ceanothus cuneatus, Nutt. Three to 12 feet high.
Ceanothus rigidus, Nutt. Five feet.
Ceanothus verrucosus, Nutt.

ROSACEÆ: Rose family.
Prunus demissa,[4] Walpers. Wild Cherry. Shrub or small tree.
Prunus ilicifolia, Walpers. "Islay." A shrub 8 to 12 feet high; evergreen.
Prunus fasciculata, Gray. Two to 3 feet high.
Prunus Fremonti, Watson.
Spiræa discolor, Pursh., var. *dumosa*, Watson. Low shrub.

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[1] See pp. 171, 172. [2] See No. 88, p. 189. [3] See Bull. Calif. Acad., 2d. S. I., 271. [4] See No. 47, p. 174.

ROSACEÆ : Rose family—Continued.

Rubus Nutkanus, Moç. Three to 8 feet high.

Rubus leucodermis, Dougl. Three to 5 feet high.

Rubus ursinus, Cham. & Schl. Trailing.

Chamæbatia foliolosa, Benth. One to 2 feet high.

Purshia tridenta,[1] D C. Two to 8 feet high.

Cercocarpus parvifolius,[2] Nutt. Mountain Mahogany. Two to 10 feet high.

Andenostoma fasciculatum, Hook. & Arn. "Grease-wood." Two to 10 feet high; shrub-like; evergreen foliage.

Andenostoma sparsifolium, Torr. "Deer-brush." Shrub or small tree; evergreen.

Rosa Californica, Cham. & Schlecht. Two to 8 feet high.

Heteromeles arbutifolia, Roemer. "Tyon," "Tollon." Four to 15 feet high.

RUTACEÆ: Rue family.

Thamnosma montanum, Torr. One to 2 feet high.

Cneoridium dumosum, Hook, f. Two to 4 feet high.

SALICINEÆ: Willow family.[3]

Salix lævigata, Bebb. A tree 15 to 20 feet high. Two varieties are distinguished from the type; var. *angustifolia* and var. *congesta*.

Salix lasiandra, Benth., var. *lancifolia*, Bebb.

Salix longifolia, Muhl. Three to 15 feet high. Two varieties are known; *argyrophylla*, Anders., and *exigua*, Bebb.

Salix sessilifolia, Nutt., var. *Hindsiana*, Anders.

Salix lasiolepis, Benth. Under favorable conditions a tree 40 to 60 feet high. Two varieties; *Bigelovii*, Bebb; *falax*, Bebb.

Populus trichocarpa, Torr. & Gray. Thirty to 50 feet high. One variety, *cupulata*, Watson.

Populus Fremonti, Watson, var. *Wislizeni*, Watson. A large tree.

SAPINDACEÆ: Soapberry family.

Æsculus Parryi, Gray. Buckeye. A shrub occurring farther south, but possibly to be met with in this range.

Acer macrophyllum, Pursh. Broad-leaved Maple. Tree 50 to 90 feet high.

SAXIFRAGACACEÆ: Saxifrage family.

Ribes speciosum, Pursh. Gooseberry. Six to 10 feet; stout.

Ribes Menziesii, Pursh. Gooseberry. Two to 6 feet.

Ribes viscosissium, Pursh. Low.

Ribes sanguineum, Pursh. Currant. Two to 12 feet.

Ribes sanguineum, Pursh., var. *malvaceum*.

SCROPHULARIACEÆ: Figwort family.

Pentstemon ternatus, Torr. Two to 4 feet.

Pentstemon antirrhinoides, Benth. One to 5 feet.

Pentstemon cordifolius, Bth.

Pentstemon Rothrockii, Gray.

SOLANACEÆ: Nightshade family.

Lycium Cooperi, Gray.

Lycium Californicum, Nutt. Two to 4 feet; spiny.

Lycium Torreyi, Gray. Three to 8 feet.

Lycium Andersonii, Gray, var. *Wrightii*, Gray. Two to 4 feet.

STERCULIACEÆ.

Fremontia Californica, Torr. Ten to 20 feet high.

TAMARISCINEÆ: Tamarisk family.

Fouquiera splendens, Engelm. Candlewood. Often 10 to 20 feet high.

VITACEÆ: Grape Vines.

Vitis Californica, Benth.

ZYGOPHYLLACEÆ:

Larrea Mexicana,[4] Moric. "Creosote bush." Four to 10 feet high.

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[1] See *Purshia*, p. 192. [2] See No. 51, p. 175. [3] See this family, p. 185. [4] See *Larrea* p. 190.

THE NEEDS OF THE YELLOWSTONE NATIONAL PARK.

U. S. GEOLOGICAL SURVEY,
Washington, December 27, 1887.

SIR: During your visit to the Yellowstone Park last summer you expressed so warmly your keen appreciation of the region as a forest reservation that I desire to call your attention to some of the more salient features of the country, and to point out what I consider the important reasons for not only maintaining the national park, but for enlarging its boundaries. In the arid and sparsely timbered regions of the eastern ranges of the Rocky Mountains few areas equal and none surpass the Yellowstone Park in its advantages to the nation as a forest reservation. While much may rightly be said in favor of the maintenance of the park, based upon sentimental grounds, the necessity of protecting the scientific curiosities, the advantages of the place as a game-preserve, and the benefits to be derived from it as a health resort, the object of first importance is the preservation of its timber. The park is a natural reservoir, adapted by geographical position to receive a copious snow and rain-fall, and by its topographical structure to store up the waters which it receives.

In its broader physical features the Yellowstone Park is an elevated volcanic plateau shut in on the south, east, north, and northwest by mountains rising from 2,000 to 4,000 feet above the general level of the inclosed table-land. It presents a broken, roughly undulating surface, varying from 7,000 to 8,500 feet above sea-level, with an average elevation of about 8,000 feet.

The Gallatin Range, with Electric Peak a culminating point, shuts in the park on the west and north. To the northeast the Snowy Range, deriving its name from the white-capped summits, towers high above the plateau. Along the eastern side of the park for more than 80 miles stretches the Absaroka Range, which rises as a bold, unbroken barrier above the table-land, many of the mountain tops reaching elevations varying from 10,000 to 11,500 feet above sea-level. To the southward the plateau is rimmed in by the Grand Tetons and Wind River Range. All these surrounding mountains, covered with snow the greater part of the year, are constantly pouring immense volumes of water into the plateau region. The continental water-shed enters the park near its southeast corner, crosses the summit of Two Ocean Plateau, and with an irregular, winding course follows along the top of the volcanic lava-flow in a general northwesterly direction, leaving the park nearly west of the Upper Geyser Basin.

Five main channels carry off the waters from the park to the valleys below. On the eastern side of the great water-shed the Yellowstone, Madison, and Gallatin contribute their waters to the Missouri, while the Snake and Falls Rivers on the opposite side add their share to the Columbia. The Yellowstone River, already a magnificent stream before it leaves the mountains, drains more than one-half the area of the park, including the entire eastern border, together with the eastern side of the Gallatin Range, which, through the Gardiner River, pours its waters into the Yellowstone. The streams upon the western slope of the Gallatin Range empty into the Missouri by the Gallatin River. Both the Gibbon and the Firehole find their sources among springs on the plateau, and after draining the principal geyser basins unite to form the Madison. Falls River, a picturesque stream, collects the large drainage from the Pitchstone Plateau and the southern end of the Madison Plateau, and leaves the park at the extreme southwest corner. Snake River, however, drains the greater part of the country on the west side of the water-shed, collecting immense bodies of water coming from the northern ends of the Teton and Wind River Ranges and the southern slopes of the volcanic plateau. Taken together, these accumulated waters make the Snake a broad river before it leaves the mountains.

On the plateau, upon both sides of the water-shed, occur several large bodies of water, Yellowstone, Shoshone, Lewis, and Heart Lakes being especially noteworthy for their size and beauty. Scattered over the country, both on the plateau and in the surrounding mountains, are numerous smaller lakes and ponds, occupying for the most part shallow basins of glacial origin. The view from the summits of either Mount Sheridan or Mount Hancock presents a grand and picturesque scenery of diversified forms, and a country so dotted over with lakes as to receive the appellation of the lake region of the Park. Thousands of hot springs add their waters to the cold water of the surface. Meadows, marshes, and swampy areas characterize the entire area in strong contrast with most Rocky Mountain scenery. These lakes are the reservoirs of the larger streams. The Yellowstone is the largest lake in North America at so high an elevation (7,741 feet). It has a surface area of 121 square miles, and an indented shore-line of nearly 100 miles. Only preliminary soundings have as yet been made, but over a very considerable area the depth is known to be more than 250 feet. Less than 6 miles from the Yellowstone, in a deep depression on the plateau, lies Shoshone Lake, with an area of nearly 12 square miles. A short distance to the southward, at the west base of Mount Sheridan, occurs Lewis Lake, measuring 4½ square miles, and on the opposite side of the mountain lies Heart Lake, with a surface area of 3 square miles. All three of these lakes are important feeders of Snake River.

The greater part of the Park plateau and the adjacent mountains, more especially the western slope of the Absaroka Range, are densely covered with timber. After a careful study of the forests, I think it may be safely said that 84 per cent. of the area of the country is forest-clad. The broad bottoms of the main river valleys, the steeper mountain slopes, the meadows, marshes, and geyser basins, and the tops of ridges above timber-line, comprise the timberless areas. Frequently the broad summits of the higher elevated ridges present more or less barren areas due to the almost incessant exposure to high winds, but over the greater part of the country timber line ranges from 9,600 to 9,800 feet above sea level. Over the Park plateau the timber offers a somewhat monotonous aspect, with little variety of species. Fully two-thirds of the forest trees belong to one species, the Black Pine (*Pinus Murrayana*), a straight, slender tree which rarely attains a height exceeding 75 feet. Frequently it occurs only a few inches in diameter,[1] when it is generally known as "Lodge pole" Pine. Next to the Black Pine comes the Balsam (*Abies subalpina*), which also covers considerable areas, most frequently on steep slopes and generally on moist ground. Associated with this last species is found the Spruce (*Picea Engelmanni*), more abundant, however, on the slopes of the Absaroka Range than over the plateau. The grandest tree of the region is the Douglas, or Red Fir (*Pseudotsuga Douglasii*), which occurs scattered over the Park, more especially in the neighborhood of Mount Washburn and Specimen Ridge. The only other species common enough in any way to characterize the forest, or to call for special mention, are the *Pinus flexilis*, and its associated variety, *Pinus albicaulis*, the latter widely distributed in the southern end of the Park at high altitudes, where it occurs as a common tree on the slopes of Mount Sheridan and Mount Hancock. According to Mr. Frank Tweedy, only five genera and eight species of coniferæ are known to occur within the present Park limits, the additional species being the *Juniperus communis* and *J. Virginiana*, both found over very limited areas. The arborescent growth in no way equals the grand forests of California, Oregon, and Washington Territory, either in size and development of the trees or in the quality of the wood. It is in general stunted in growth, and furnishes but a poor quality of timber in comparison with the magnificent forests found to the westward. Its importance to the nation does not consist in its marketable value, but rather in its power to store up the water and to regulate the flow of streams. For this purpose it is of incalculable value, and quite as serviceable in its way as the timber of the western Cordilleras.

The life of the forest is of short duration. The scanty, gravelly soil affords at best but slight protection to the roots against the force of the winds blowing almost incessantly from the west, as is only too well shown in the extensive acreage of fallen timber. On the other hand, I know of no region throughout the Rocky Mountains where the conditions seem so favorable for a young growth. During the five years that I have carefully observed the forests nothing has so impressed me as the rapid, healthy development of the young trees which in a few years replace the down timber. In most instances the young growth belongs to *Pinus Murrayana*, and in every case it is the first tree to spring up over a burnt district.

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[1] Owing to its dense growth.—B. E. F.

I need not enter here into a lengthy discussion of the influence of the forest upon the supply of water. I simply desire to call your attention to the special advantages of the Yellowstone Park forest for maintaining a water supply of a country singularly well situated to gather and distribute a large annual precipitation of moisture. This uplifted mountain mass measures 90 miles in length by 60 in breadth. From the southwest the moisture-laden winds blowing across the Madison plateau precipitate immense quantities of snow and rain over the cold, wet table-land. Storms gather over the mountains at all times of the year. The annual precipitation is excessive as compared with the adjacent regions of the Rocky Mountains. Rains are of common occurrence between May and September, while during eight months of the year nearly all precipitation falls as snow, which lies upon the ground well into midsummer, and on the northern slopes, at higher altitudes, remains throughout the year. Frosts occur nearly every week during the summer, and observations in July and August for several seasons, at various stations over the plateau, show that the minimum thermometer registers below 40° every night.

The forests exert a powerful influence in sheltering the snow fields, marshes, and meadows from the direct rays of the sun and the dry moisture-absorbing winds blowing from the west. Strip the plateau and mountains of timber, and early freshets would soon lay waste the lower country in spring and leave it arid and parched throughout the summer and autumn. Not only would streams diminish, but the loose gravelly soil which now everywhere covers the Park would rapidly be washed away, laying bare the underlying rocks. The soil, with the accompanying roots and grasses, playing the part of a sponge, exert a powerful influence in maintaining the water supply. They serve to keep the ground cool and moist and allow the water to percolate slowly from the surface to innumerable springs below and thence to the reservoirs of the great rivers.

With a view of determining with some degree of accuracy the volume of water flowing from the Park, the largest lakes and streams were carefully gauged. The measurements were made in early September, 1886, not only the dryest period of the summer but the dryest season known at any time within the previous five years. Evidence was ample to show that Yellowstone Lake had fallen 20 inches below high-water mark of early July. Measurements were made of the discharge from the lake at a point on the river about one-quarter of a mile below the outlet.

The results obtained gave a minimum outflow of 1,525 cubic feet per second, or, expressed in other words, of 34,000,000 imperial gallons per hour. Shoshone, Lewis, and Heart Lakes poured into Snake River 104 cubic feet per second. With few exceptions all the principal rivers leaving the Park were gauged and the discharge from the others carefully estimated, taking as a basis the number of square miles contained in the drainage basin and the flow of the streams. The results give what may be considered as approximately the minimum discharge from the Park—a volume of water equal to 1 cubic foot per second per square mile over an area somewhat more than 4,000 square miles; or as Dr. Hallock, of the U. S. Geological Survey, who supervised the gauging of the streams, has stated it, "an amount of water which would make a river 5 feet deep and 190 feet wide, with a current of 3 miles per hour." For a region bordering on the arid plains to the eastward this is certainly an excessive amount.

According to Humphreys and Abbott, the mean annual discharge from the Mississippi River at its mouth amounts to 675,000 cubic feet per second from a drainage basin of 1,147,000 square miles. This gives .53 cubic feet per second per square mile, or a trifle more than one half the minimum estimate for the Yellowstone Park country. Surely is it not one of the treasures of the nation, to be carefully guarded in every possible way?

If the broad valley of the Lower Yellowstone from Glendive to Livingston is ever to be occupied by an agricultural population, they will at no distant day need all the water flowing from the sources of the river for purposes of irrigation. In the Gallatin Valley, the finest wheat region in Montana, the hard-working farmers are already quarrelling over the distribution of the water running into their inadequately supplied irrigating ditches, while the equally industrious wood-chopper is busily cutting away the timber from the headwaters of the streams in the mountains.

In another way this broad forest-protected reservoir is singularly well situated to be of incalculable service to the nation. Throughout the summer the prevailing dry winds from the west in their passage across this moist mountainous region absorb immense quantities of water ready under favorable conditions to be again precipitated over the agricultural and grazing lands to the eastward. In camping near timber line for weeks at a time, I have never failed to be impressed with the absorbing powers of these winds, the effect of which may be seen upon the snow fields any hot summer day. The melting of the snow and the running down of the water frequently appears inconsiderable as compared with the absorbing power of the hot, thirsty winds. Where all the available lands on the Great Plains is being taken up for settlement by a rapidly advancing civilization, the economic distribution of the Park waters is a question of the utmost importance to the nation.

It is proposed to extend the boundaries of the Yellowstone Park to the south and east so as to include a dense forest region abounding in mountain torrents, the headwaters of the Yellowstone and Snake Rivers. At the time the Park was set aside by act of Congress in 1872 but little was known of the region and its relations to the adjacent country, and still less was its real value appreciated as one of the nation's most available reservoirs. This proposed enlargement embraces all the water draining into the Yellowstone river and lake from the Absaroka range and all affluents of the Snake from the northern spurs of the Grand Tetons and Wind River range. To accomplish this enlargement necessitates placing the boundaries 25 miles farther to the eastward and 9 miles to the southward of the present lines. By this addition to the domain of the Park the headwaters and timber areas around Soda Butte, Cache Calfee, Miller, and the Lamar Rivers on the west side of the range, and Crandall, Sunlight, and Dead Indian Creeks, tributaries to Clark Fork and the Stinking Water, an affluent of the Big Horn, which ultimately drains into the Yellowstone, on the east side, will fall within the reservation.

Unless protected, encroachment will soon be made upon this valuable inheritance of the nation. No serious difficulties arise against placing this additional territory within the Park forever. If timber lands near the sources of our large rivers are to be carefully guarded by national legislation there is no better place to begin the work than right here at the headwaters of the Yellowstone and Snake, which send their waters from the heart of the continent to both the Atlantic and Pacific.

Very truly, yours,

ARNOLD HAGUE.

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SUMMARY OF LEGISLATION FOR THE PRESERVATION OF TIMBER OR FORESTS ON THE PUBLIC DOMAIN.

By N. H. Egleston,

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The earliest action of the General Government having regard to the preservation of timber was in 1799, when Congress appropriated $200,000 for "the purchase of growing or other timber, or of lands on which timber is growing, suitable for the Navy, and for its preservation for future use." The special object of this legislation was to secure a supply of Live-Oak timber, which was considered peculiarly valuable for ship-building and was in great demand for that purpose, both at home and abroad, while its growth was confined to a limited portion of our territory in the vicinity of the Gulf. Two small islands on the coast of Georgia, containing together about 2,000 acres, were purchased under the act of 1799. Another act (Revised Statutes, section 2458), having the same object in view, was passed in 1817, by which the Secretary of the Navy was directed to cause lands producing Live Oak or Red Cedar to be explored, and to have selections made of tracts necessary to furnish for the Navy a sufficient supply of such timbers. Under this act 19,000 acres in Louisiana, which had recently become ours by purchase from France, were reserved.

Additional enactments were made in 1820 and 1827, by which the selection of lands to be reserved was intrusted to the surveyor of Public Lands in place of agents appointed by the Secretary of the Navy, and the President was authorized to withhold such lands from sale.

In 1822, an act was passed (Revised Statutes, section 2460), authorizing the President to employ the land and naval forces so far as necessary effectually to prevent the felling or other destruction of timber in Florida, and to take such other measures as might be deemed advisable for the preservation of timber there. (Florida had recently been ceded to the United States by Spain, and was known to abound in Live-Oak timber.)

In 1831, an act was passed (Revised Statutes, sections 2461, 2462, and 2463) of wider scope than that of 1822. This made it a felony, with penalty of fine and imprisonment, to cut or remove timber from any of the public lands, whether reserved or not, except for the use of the

Navy, and subjected any vessel transporting such timber without proper authority and for any other purpose than for the use of the Navy, to confiscation and the master ot the vessel to a fine.

This act is the one under which, up to the present time, all the protection they have had has been secured to the public forests, the Supreme Court having construed the act (9 How., 351) as authorizing the protection of all timber on the public lands, and punishment for trespass upon the same. Under the act of 1831, the Treasury Department undertook a partial oversight and protection of timber on the public lands through its ordinary agents. In 1855 this oversight was transferred to agents of the Land Department, registers and receivers being instructed to act also as timber agents, but without any additional compensation. Where trespass was willfully committed, payment of stumpage was demanded or the timber was seized and sold and the proceeds paid into the Treasury. Where the trespass was committed ignorantly, actual entry of the land only was required, with payment of the usual entry charges.

The first appropriation for the payment of agents specially employed for the protection of timber on the public lands was made in 1872, when $5,000 were appropriated. A like sum was appropriated annually thereafter for five years. In 1878, to meet expenses for suppressing depredations upon timber on the public lands, $25,000 were appropriated. Subsequent appropriations for this purpose are noticed in another place.

The following synopsis shows the course of legislation by the General Government in behalf of the forests and timber lands since the passage of the act of 1831.

It will be noticed that, with the exception of the acts of 1876, 1878, 1880, and 1883, none of the many bills which have been proposed have been given the form of law. But the failures to secure legislation may be as instructive and as important in a correct history of forestry in our country as the record of successes. This will justify the somewhat extended, though not exhaustive, list of bills here given:

Year.	Congress.	House in which originated.	Object of bill.	Action taken.
1871	41st, 3d sess.	H. R. 2930, Sargent.	For the sale of timber lands in California and Oregon.	Referred to Committee on Public Lands.
1871	41st, 3d sess.	H. R. 3005, Sargent.	To authorize the sale of timber lands in California, Oregon, and Washington Territory, not exceeding 640 acres to one person or association, without residence, at $2.50 per acre.	Passed in House. In Senate referred to Committee on Public Lands.
1871	42d, 1st sess.	H. R. 274, Garfielde.	Same as the preceding	Referred to Committee on Public Lands.
1872	42d, 2d sess.	H. R. 2197, Haldeman.	To encourage the planting of trees and the preservation of woods on the public domain. (The first real and comprehensive forestry bill.)	Referred to Committee on Agriculture. Reported favorably. Failed of passage—81 yeas, 87 nays.

Year.	Congress.	House in which originated.	Object of bill.	Action taken.
1872	42d, 2d sess.	....	Resolution that the Committee on Agriculture inquire whether a certain percentage of each quarter section of public lands sold must be planted with trees or a certain percentage of existing forests preserved for the purpose of preventing or remedying drouth.	No action.
1873	3d, 1st sess.	H. R. 410, Page.	Same as Garfielde bill (274) above.	Referred to Committee on Public Lands. June 3, reported back with amendments and recommitted. December, 1874, H. R. bill 4194 reported by committee as substitute. Passed February 22, 1875. In Senate February 22, referred to Committee on Public Lands.
1874	43d, 1st sess.	Senate 471, Boutwell.	For the survey and disposal of the timber lands of the United States. Miners may buy stumpage, not more than 160 acres, till that is cut, at $2.50 per acre. Homesteaders may buy 40 acres of timber land near agricultural land at same price.	Referred to Committee on Public Lands. Reported with amendments.
1874	43d, 1st sess.	H. R. 2497. Herndon.	For the appointment of a commission for inquiry into the destruction of forests and into the measures necessary for the preservation of timber.	Referred to Committee on Public Lands. Reported back with H. R. 2540 as a substitute.
1874	43d, 1st sess.	H. R. 2540, Dunnell.	For the appointment of a commissioner to inquire into the destruction of forests and into the measures necessary for the preservation of timber.	Reported by Committee on Public Lands as a substitute for preceding bill, H. R. 2497.
1875	43d, 2d sess.	H. R. 4430, Averill.	To regulate the survey and sale of the timber lands of the United States. Commissioner of the Land Office to survey and appraise lands more valuable for their timber than for agricultural use. Such lands not to be entered under homestead or preemption laws, but appraised and offered at public sale, and if not sold then to be open to private entry at a price not less than the appraisal.	Referred to Committee on Public Lands.
1875	44th, 1st sess.	H. R. 323, Dunnell.	To regulate the survey and sale of the timber lands of the United States. Same bill as the preceding.	Referred to Committee on Public Lands.
1875	44th, 1st sess.	Senate 2, Clayton.	To repeal section 2303 of the Revised Statutes, thereby opening timber lands in Southern States to private entry in unlimited quantities and at the reduced price of $1.25 per acre.	Referred to Committee on Public Lands. Reported back and passed. In H. R. referred to Committee on Public Lands. Passed H. R. and became a law July 4, 1876, through inaction of the President.
1875	44th, 1st sess.	Senate 6, Kelley.	For sale of timber lands in California, Oregon, and the Territories. Same as previous bills with similar title.	Referred to Committee on Public Lands. Passed Senate February, 1876. In H. R., February, 1876, referred to Committee on Public Lands. March, 1877, House refused to suspend rules and pass the bill.

Year.	Congress.	House in which originated.	Object of bill.	Action taken.
1876	44th, 1st sess.	H. R. 660, Maginnis.	For the sale of the timber lands in the Territories. Lands valuable for timber but not for cultivation to be sold at $2.50 per acre, not more than 40 acres to one person.	Referred to Committee on Public Lands.
1876	44th, 1st sess.	H. R. 1191, Sayler.	To regulate the survey and sale of the timber lands of the United States. Lands valuable chiefly for timber not to be subject to entry under pre-emption or homestead laws, but to be appraised and sold at not less than the appraised value.	Referred to Committee on Public Lands. Reported with amendments and recommitted.
1876	44th, 1st sess.	H. R. 1310, Dunnell.	For the appointment of a commission, etc. Same as preceding bill (H. R. 2540).	Referred to Committee on Public Lands. No opportunity was afforded for regular action on the bill, but, on motion of Mr. Dunnell, the substance of it was added as an amendment to the general appropriation bill, and became a law August, 1877.[*]
1876	44th, 1st sess.	H. R. 2075, Fort.	For the preservation of the forests adjacent to the sources of navigable rivers and other streams. Such timber lands to be withdrawn from sale and a commission to determine what should be reserved so as to prevent scanty supply of water.	Referred to Committee on Public Lands.
1877	45th, 1st sess.	H. R. 797, Maginnis.	For the sale of timberlands in the Territories. Same as bill (660) of Mr. Maginnis in Forty-fourth Congress.	Referred to Committee on Public Lands.
1877	45th, 1st sess.	H. R. 1154, Pacheco.	To regulate the survey and sale of timber lands of the United States. Same as bills in the Forty-third and Forty-fourth Congresses.	Referred to Committee on Public Lands.
1877	45th, 1st sess.	H. R. 1525, Herbert.	To put into market certain timber lands of the United States. Declaring subject to entry, in any quantity, all public timber lands in Alabama, Louisiana, and Minnesota which have been subject to entry in limited quantities for twenty years, and after entry of such lands to be no prosecution for trespass or timber cutting.	Referred to Committee on Public Lands.
1878	45th, 2d sess.	H. R. 2658, Maginnis.	To provide for the entry of unsurveyed timber lands. Allowing the owner of a mine to take 160 acres of timber land for every 20 acres of mineral land owned by him, and the owner of agricultural land 40 acres for every quarter section, and for every $20,000 expended on a mill or furnace 640 acres may be taken at $2.50 per acre.	Referred to Committee on Public Lands.

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[*] By this enactment the Commissioner of Agriculture was directed to appoint a competent person to make the contemplated inquiries and investigations. The Commissioner appointed for this work Mr. F. B. Hough, and the prosecution of the work led to the establishment of the Forestry Division in the Department of Agriculture. The result of Mr. Hough's inquiries has been published in three volumes. The work begun by him has been continued by his successors in charge of the Forestry Division, so far as the small appropriation made by Congress for the purpose would allow, and additional reports have been published.

Year.	Congress.	House in which originated.	Object of bill.	Action taken.
1878	45th, 2d sess.	H. R. 3981, Patterson.	Withdrawing lands chiefly valuable for timber from entry under pre-emption or homestead laws. Such lands to be surveyed and divided into "timber lands" and "mineral timber lands." On the latter the timber only to be sold. Timber lands to be appraised and sold by commissioners. Such lands as are needed for irrigation purposes to be withheld from sale.	Reported by Committee on Public Lands as a substitute for several bills Recommitted.
1878	45th, 2d sess.	....	$25,000 appropriated to suppress depredations on public timber.	
1878	45th, 2d sess.	Senate 923, Sargent.	Allowing sale of timber lands unfit for cultivation in California, Oregon, Nevada, and Washington Territory at $2.50 per acre. No one person or association to enter more than 160 acres.	Referred to Committee on Public Lands. Passed Senate. Reported to and passed H. R. Approved by President June 3.
1878	45th, 2d sess.	H. R. 3800, Wren.	Bill similar to next below	Referred to Committee on Public Lands.
1878	45th 2d sess.	Senate 20, Chaffee.	Allowing residents of Colorado, Nevada, and other Territories, and all mineral districts, to fell and remove, for building and other domestic purposes, trees on mineral lands.	Referred to Committee on Public Lands. Amended and passed by Senate. Passed H. R. and signed by President June 3.
1879	45th, 3d sess.	H. R. 6087, Dunnell.	To regulate the survey and sale of timber lands. Same as bill presented December, 1875 (H. R. 323), providing that timber lands more valuable for lumber than for agricultural purposes be reserved from entry under homestead or pre-emption laws, appraised, and sold to highest bidder, but not for less than appraisement.	Referred to Committee on Public Lands.
1879	46th, 1st sess.	H. R. 1164, Dunnell.	To regulate the survey and sale of timber-lands of the United States. Same as last bill above.	Referred to Committee on the Public Lands.
1880	46th, 2d sess.	H. R. 6321, Carlisle.	To prevent depredations upon timber in the Indian Territory.	Referred to Committee on Indian Affairs.
1880	46th, 2d sess.	H. R. 6340, Downey.	Authorizing citizens of Colorado, Nevada, and the Territories, to fell and remove timber on the public domain, for mining and domestic purposes. Extending the act of June, 1878.	Referred to Committee on the Public Lands.
1880	46th, 2d sess.	Senate 1812, Coke.	To prevent depredations upon timber on Indian reservations.	Reported from the Committee on Indian Affairs.
1880	46th, 2d sess.	H. R. 6371, Hooker.	To prevent depredations upon timber on Indian reservations. Same as last bill above.	Referred to Committee on Indian Affairs.
1880	46th, 2d sess.	H. R. 1816, Herbert.	Act condoning trespass on public lands prior to March, 1879. Persons against whom suits were pending prior to that date to enter lands trespassed upon and pay accrued costs, thereupon suits to be discontinued. At same time price to be paid for lands to be reduced from $2.50 to $1.25.	Approved by the President June 15, 1880.
1882	47th, 1st sess.	Senate 760, Teller.	For the classification of the public lands in Colorado and the sale of timber thereon. The Secretary of the Interior to regulate the sale, and may reserve timber on head-waters of streams and on mountains.	Referred to Committee on Public Lands.

Year.	Congress.	House in which originated.	Object of bill.	Action taken.
1882	47th, 1st sess.	Senate 1641, Teller.	To amend act of 1878, so as to allow any one in Western States and Territories to remove timber from mineral lands for any purpose, under rules and regulations of the Secretary of the Interior and payment of $2.50 per acre for the timber. No timber to be cut by mill-owners or lumber manufacturers.	Referred to Committee on Public Lands.
1882	47th, 1st sess.	Senate 1826, Sherman.	For the preservation of woods and forests adjacent to sources of navigable rivers. Same as bill introduced in H. R. 1st session, Forty-fourth Congress.	Referred to Committee on Agriculture.
1882	47th, 1st sess.	H. R. 6315, Butterworth.	For the preservation of woods, etc. Same as Senate bill next above.	Referred to Committee on Agriculture.
1882	47th, 2d sess.	H. R. 6997, Strait.	To provide for the classification and disposition of pine timber-lands. Such lands, chiefly valuable for their timber, not to be subject to pre-emption or homestead entry, but to be appraised by the Secretary of the Interior, and sold from time to time at public sale, for not less than two-thirds the appraisement. Mineral lands exempt from the act.	Referred to Committee on the Public Lands.
1883	47th, 2d sess.	H. R. 7509, Dwight.	To regulate the sale of the timber-lands of the United States. Similar to last bill above, but lands remaining unsold to be subject to private entry at the appraised value.	Referred to Committee on the Public Lands.
1883	47th, 2d sess.	Senate 2496, Tabor.	For the protection and preservation of the forests of the United States. One hundred thousand dollars to be appropriated to Colorado for the establishment of an experiment station under the direction of the Department of Agriculture.	Referred to Committee on Appropriations.
1883	47th, 2d sess.	H. R. 4757.	Act to exclude the public lands in Alabama from the operation of laws relating to mineral lands. (In reality an act to sell all mineral lands in Alabama as agricultural lands, at private sale, in unlimited quantities, and at the reduced rate of $1.25 per acre, to citizens or aliens.)	Approved by the President March 3, 1883.
1883	48th, 1st sess.	H. R. 832, Strait.	For the classification and disposition of pine timber-lands. Same as above bill presented in Forty-seventh Congress.	Referred to Committee on the Public Lands.
1883	48th, 1st sess.	Senate 1258, Sherman.	For the preservation of woods and forests adjacent to sources of navigable rivers, etc. Same as bill in Forty-seventh Congress.	Referred to Committee on Agriculture.
1883	48th, 1st sess.	H. R. 4811, Hatch.	For the preservation of woods, etc. Same as last bill above.	Referred to Committee on Agriculture.
1883	48th, 1st sess.	H. R. 5206, Deuster.	For the preservation of woods, etc. Same as last bill above.	Referred to Committee on Agriculture.
1884	48th, 1st sess.	Senate 1541, Dawes.	To prevent cutting of timber on military or Indian reservations.	Referred to Committee on Indian Affairs. Passed in Senate April 23. In H. R. referred to Committee on Indian Affairs.

Year.	Congress.	House in which originated.	Object of bill.	Action taken.
1884	48th, 1st sess.	Senate 1188 Cameron.	For the protection, preservation, and extension of the forests of the United States. To establish an experiment station in connection with the Department of Agriculture, west of the Mississippi River. To propagate and distribute forest trees, investigate qualities, time of growing, profit, etc. One hundred thousand dollars appropriated.	Referred to Committee on Agriculture and Forestry.
1884	48th, 1st sess.	Senate 1824, Edmunds.	Act to establish a forest reservation on the head-waters of the Missouri and Columbia Rivers.	Passed Senate June 1884. In House printed.
1884	48th, 2d sess.	Senate 2451, Miller.	For the protection of forests on the public domain. Withdraws all timber land from sale under existing laws. Forest Commission to be appointed to examine and classify forest lands and determine what should be permanently reserved. Timber on reserved lands to be sold under direction of the Commissioner of the Land Office.	Referred to Committee on Agriculture. Reported favorably.
1885	49th, 1st sess.	Senate 581, Edmunds.	To establish a forest reservation in Montana. Same as bill S. 1824, in Forty-eighth Congress.	Referred to Committee on Agriculture. Reported favorably. Passed Senate. In H. R. on calendar.
1885	49th, 1st sess.	H. R. 379, Payson.	To repeal act of 1878, for the sale of timber-lands in California, Oregon, Nevada, and Washington Territory.	Referred to Committee on the Public Lands.
1885	49th, 1st sess.	H. R. 2946, Hatch.	For the preservation of woods and forests adjacent to sources of navigable rivers, etc. Same as bill offered in Forty-eighth Congress.	Referred to Committee on Agriculture.
1885	49th, 1st sess.	Senate 551, Sherman.	For the preservation of woods and forests adjacent to sources of navigable rivers, etc. Same as bill next above.	Referred to Committee on Agriculture.
1886	49th, 1st sess.	H. R. 5556, Oates.	To define and punish the offense of setting fire to woods or forests belonging to the United States.	Referred to Committee on Judiciary. Reported at second session, with amendments, and placed on the Calendar.
1887	49th, 2d sess.	H. R. 10430, Markham.	For the protection of forests in California. To withdraw from sale Government forest lands in California not suited to agriculture. Such lands not to be alienated from the Government, but to be placed temporarily under the management of the forest commissioners of California. Fifty thousand dollars appropriated to carry out the act.	Referred to Committee on Public Lands. Reported favorably.
1888	50th, 1st sess.	H. R. 6045, S. V. White.	For the protection and administration of the forests on the public domain. Provides for the classification of forest lands, the reservation of a proper amount of forest land from sale, the timber on the same alone being sold under direction of forest commissioners to be appointed, who are to have entire management of the public forests. Timber lands not necessary for reservation to be sold.	Referred to Committee on Public Lands.

Year.	Congress.	House in which originated.	Object of bill.	Action taken.
1888	50th, 1st sess.	Senate 1779, Hale.	For the protection and administration of the forests on the public domain. Same as H. R. bill 6045 above.	Referred to Committee on Agriculture and Forestry.
1888	50th, 1st sess.	H. R. 1353, Weaver.	To further amend the public-land laws, and for the preservation of natural forests on the public domain, the protection of water supply, and for other purposes.	Referred to Committee on Public Lands.
1888	50th, 1st sess.	H. R. 7901, Holman.	To secure to actual settlers the public lands adapted to agriculture, to protect the forests on the public domain, and for other purposes.	Reported by Committee on Public Lands as a substitute for H. R. bill No. 6045 and other bills relating to the public lands. Passed. In Senate referred to Committee on Public Lands.
1888	50th, 1st sess.	Senate 2510. Teller.	To amend act authorizing citizens of Colorado, Nevada, and the Territories to fell and remove timber on the public domain for mining and domestic purposes.	Referred to Committee on Public Lands.
1888	50th, 1st sess.	Senate 2877 Teller.	Authorizing citizens of Colorado, Nevada, and the Territories to fell and remove timber on the public domain for mining and domestic purposes.	Referred to Committee on Public Lands.

To give a more complete view of the action of the Government in its bearings upon forestry, it seems proper to append to the foregoing synopsis the following record of legislation, actual as well as only proposed:

TIMBER CULTURE ACTS.

Year.	Congress.	House in which originated.	Object of bill.	Action taken.
1873	42d, 2d sess.	Senate 680, Hitchcock.	To encourage the growth of timber on Western prairies. A person planting 40 acres of timber trees on Government land to be entitled to 160 acres at the expiration of ten years. The so-called timber-culture act.	Referred to Committee on Public Lands. Reported favorably and passed. Approved March 3, 1873.
1874	43d, 1st sess.	H. R. 743, Dunnell.	To amend the above act. Confines privilege of entry to heads of families or persons over twenty-one years of age and to citizens of the United States. Reduces the time for perfecting title to eight years. Restricts the amount to be entered by one person to 160 acres. Allows homesteaders to obtain patent by planting one-sixteenth of homestead with trees.	Passed and approved March 13, 1874.
1876	43d, 1st sess.	H. R. 2427.	To amend act of 1873. Allows extension of time for perfecting title in case of the destruction of trees by grasshoppers; also permits seeds and nuts to be planted instead of trees.	Referred to Committee on Public Lands. Reported favorably, passed, and approved May 20, 1887.

TIMBER CULTURE ACTS—Continued.

Year.	Congress.	House in which originated.	Object of bill.	Action taken.
1878	45th, 2d sess.	H. R. 3235, Strait.	To amend the act of 1873. Reducing the number of acres to be planted to 10 for every quarter section and in the same proportion for smaller quantities, but requiring closer planting—twenty-seven thousand trees per acre. Five acres to be broken first year and 5 the second, and planted with trees in the third and fourth years. Repeals the homestead provision of the act of 1874.	Reported with amendments by committee, passed, and approved June 14, 1878.
1881	47th, 1st sess.	H. R. 430, Ryan.	To amend the act of 1878. Specifying the kinds of trees to be planted.	Referred to Committee on Public Lands.
1882	47th, 1st sess.	H. R. 4497, Deering.	To repeal the act of 1878..........	Referred to Committee on Public Lands.
1885	49th, 1st sess.	Senate 65, Dolph.	To repeal all laws for the pre-emption of public lands and those allowing entries for timber culture, the sale of desert lands, etc.	Referred to Committee on Public Lands.
1885	49th, 1st sess.	H. R. 452, Cobb.	To repeal all laws for the pre-emption of public lands and those allowing entries for timber culture.	Referred to Committee on Public Lands.
1885	49th, 1st sess.	H. R. 380. Payson.	To repeal pre-emption and timber-culture laws. Nearly identical with bill 452.	Referred to Committee on Public Lands.
1886	49th, 1st sess.	H. R. 5210, Henley.	To repeal all laws for the pre-emption of public lands and for timber-culture entries.	Referred to Committee on Public Lands.
1886	49th, 1st sess.	H. R. 1238, Strait.	To amend the act of 1878..........	Referred to Committee on Public Lands.
1888	50th, 1st sess.	Senate 2893, Paddock.	To amend act to encourage the growth of timber on the western prairies.	Referred to Committee on Public Lands.

FOR THE ESTABLISHMENT AND ENDOWMENT OF FORESTRY SCHOOLS.

Year.	Congress.	House in which originated.	Object of bill.	Action taken.
1882	47th, 1st sess.	Senate 1880, McMillan.	To aid in the endowment of a school of forestry at Saint Paul. Granting 300 sections of public land for the purpose.	Referred to Committee on Agriculture.
1883	47th, 2d sess.	H. R. 7440, Pettigrew.	To grant lands to Dakota for the purpose of establishing a school of forestry. Granting 400 sections of land for the purpose.	Referred to Committee on Public Lands.
1884	48th, 1st sess.	H. R. 4361, Raymond.	To grant lands to Dakota for the purpose of establishing a school of forestry. Same bill as the preceding.	Referred to Committee on Public Lands.
1886	49th, 1st sess.	H. R. 2826, Gifford.	To grant lands to Dakota for the purpose of establishing a school of forestry. Same as two preceding bills.	Referred to Committee on Public Lands.

THE CLIMATE OF COLORADO AND ITS EFFECT ON TREES.

By GEORGE H. PARSONS, Colorado Springs, Colo.

A discussion of climatic effects upon trees in Colorado must necessarily, from the lack of exact records, be rather general in its nature. It is to be regretted that no experimental plantations of trees have been made in various parts of the State, where the behavior of different species, under the peculiar conditions of this climate, could be regularly observed and noted. Such a systematic record, showing in a concise form the history of each tree, would be of much more benefit than the general and irregular observations of any number of planters, provided, always, that the observer is thoroughly trained in the work he has to do, otherwise his records will be worse than useless, like many of the tables of meteorological phenomena, laboriously constructed after the most approved scientific methods, which are now thrown aside as fallacious.

In the absence of these experimental stations and skilled observers, the province of science may be to examine and record such irregular observations as may be found. This is what I propose to do, confining myself to the results of my own general observations, and that of others, regarding trees.

A detailed description of the whole climate of so large a State as Colorado, and one of so great variation of surface, will be impossible in the limits of this paper. The discussion will therefore be more particularly confined to the best-known and more densely peopled portion lying where plain and mountain meet around the cities of Denver, Colorado Springs, and Pueblo. Indeed, only in this region have climatic observations been taken and recorded for a period long enough to give any reliable data of the average conditions; and only here have trees been planted to an extent sufficient to enable the observer to learn some of the effects of the climate upon them.

Still, a study of the climate of this region will be, to a certain extent that of the whole State, for the difference between this and any other portion is only one of degree. The temperature will change with altitude and latitude, and the moisture among the mountains will be greater than on the plains.

That we may enter more intelligently upon the consideration of the climate of Colorado, we will briefly glance at the various influences that control a climate.

Great altitude has perhaps the most important influence on climate, because of the rarity of air that accompanies it, producing rapid evaporation, dryness, variability, and extremes of temperature, clearness of skies, and all the effects opposite to those of the sea-level, where the thick stratum of humid atmosphere intercepts the sun's rays, retains heat, obstructs radiation, and produces equability of temperature. Low humidity is the main characteristic of high elevations, and is caused principally by the lower temperature reigning at such elevations, but also by the diminution of atmospheric pressure, allowing less moisture to be held in a given space of air at a given temperature than at lower levels. Authorities state that there is an average lowering of temperature of three degrees Fahrenheit for each thousand feet of ascent, and this cooling lessens the capacity of air to contain moisture.

Latitude has a strong influence on climate, acting in much the same way as altitude; the effects of a high degree of latitude being, in a general way, similar to those of a great altitude. Professor Loomis states that beyond the parallel of sixty degrees north latitude, at a short distance from the ocean, the mean annual rain-fall seldom exceeds 10 inches.

Distance from the ocean naturally promotes dryness, and to this fact is due, in no small degree, the uniform lack of humidity in the atmosphere upon the extensive plateaus of Wyoming, Colorado, and New Mexico, which is not found in the high altitudes of Switzerland. The evaporation constantly going on over the ocean and all bodies of water, supplying the atmosphere with moisture, which returns to the thirsty land in rain, is wanting in the elevated interior of our continent. And there can be no satisfactory compensation on our open plains for this absence of water distribution, as long as there are no forests, undergrowth, or thick grasses to prevent evaporation and drying of the land, and to provide by their natural reservoirs and springs and differences of temperature a substitute for the ocean. A far inland position also has a powerful influence upon temperature. The specific heat of land being only one quarter that of water, it both absorbs and gives out heat more rapidly, consequently the more land the greater the heat and the wider the fluctuation, especially when there is nothing to obstruct the sun's rays or the earth's radiation.

High mountain ranges exert a powerful influence upon the moisture conditions of a climate, by intercepting the air currents which come from a distant, warm, damp region. Such currents are quickly brought to the point of saturation as they mingle with the cooler elevated atmosphere of the mountains, and precipitating their moisture in rain or snow upon the mountain sides, they pass on in a dry and highly electrical condition. Mountains also influence a climate by the shelter they afford from severe winds. They also increase the local showers by gathering and precipitating the moisture accumulated in the atmosphere by evaporation from the earth's surface. This effect of mountains is also shown by the opposite influence of level, barren plains, where not even a tree is found to intercept the moisture-laden currents.

The absorptive power of the earth has a climatic influence of greater or less degree according to the nature of the soil. A very dry atmosphere will be rarely found where the soil is composed of closely-packed clay, with a tendency to form swamps, morasses, and sloughs. On the contrary, a porous, dry sand and light, friable, loose earth absorb, to a great extent, the moisture from the air. Sand also loses its moisture more easily than clay; it heats more quickly, and also cools more rapidly.

Such are, in general, the influences that control a climate, and with a knowledge of these and of the physical nature of this selected section of Colorado we may form a good idea of what to expect here.

The altitude of this region, outside of the mountains, is from 5,000 to 7,000 feet above the sea. The latitude is between the thirty-eighth and forty-first parallels, about the same as the cities of Washington, Philadelphia, and New York. The distance from the Pacific Ocean is about 1,440 miles, and from the Atlantic about 2,100 miles.

The principal portion is a rolling prairie, bare and brown, except along the few water-courses, where sparse belts of cottonwood trees relieve the monotonous and desert-like appearance. The earthy billows of this ocean-like plain rise and break against the rocky slopes of a vast mountain range, running nearly north and south, and stretching westward to the Pacific. Its lofty peaks rear their summits 14,000 feet above the level of the sea, and promontories or spurs jut forth here and there into the plain. From these rocky slopes the decomposed sandstone has been washed down upon the plain below, and formed sandy, gravelly deposits of wonderful porosity and depth, capable of absorbing any quantity of rain and moisture.

And now, with this bird's-eye view of the climate, let us examine it more closely and in detail and see how it affects tree-growth. In this we shall be aided by the constancy and regularity of most of the phenomena.

The following table, compiled from the meteorological records taken in Denver for thirteen years, from 1872 to 1884, will give an idea of the climate there, as far as such observations can do so:

Table showing average climate at Denver for each month for thirteen years.

Months.	Mean temperature.	Mean daily range of temperature.	Highest observed temperature.	Lowest observed temperature.	Average maximum temperature.	Average minimum temperature.	Mean relative humidity.	Total precipitation.	No. of days rain or snow fell.	No. of clear days.	No. of fair days.	No. of cloudy days.	No. of sunny days.	Average cloudiness.	Average velocity of wind per hour.
							P. ct.	*Inch.*							*Miles.*
December	30.5	23.9	71	−25	64.4	− 7.6	55.8	.72	5	15	13	3	29	2.2	6.2
January	27.5	23.5	67	−29	60.2	−11.5	53.5	.66	5	16	11	4	28	2.0	6.5
February	31.4	21.4	72	−22	62.0	− 2.7	53.5	.46	5	13	12	3	27	2.2	6.0
Winter	29.8	.....	72	−29	62.2	− 7.3	54.3	1.84	15	44	36	10	84	2.1	6.2
March	39.7	20.6	81	−10	71.3	8.6	48.8	.86	6	14	11	6	28	2.6	7.4
April	46.0	21.1	83	4	76.9	17.3	49.2	1.83	8	10	13	7	25	3.2	7.3
May	53.9	22.5	92	27	85.4	31.6	49.2	3.17	11	9	15	7	28	3.3	7.1
Spring	47.2	.....	92	−10	77.9	19.2	49.1	5.86	25	33	39	20	81	3.0	7.3
June	66.8	24.3	99	37	94.4	41.7	40.8	1.59	7	13	13	4	29	2.5	6.3
July	72.2	28.3	102.3	42	97.4	50.2	46.4	1.78	9	12	15	4	30	2.8	6.4
August	70.5	23.8	105	44	96.0	49.4	47.4	1.54	10	12	14	5	30	2.8	5.7
Summer	69.8	.....	105	37	95.9	47.1	44.9	4.91	26	37	42	13	89	2.4	6.1
September	60.9	26.8	93	28	89.7	35.2	43.8	.90	5	17	9	4	29	2.0	5.5
October	50.3	26.7	86	1	82.1	20.7	45.0	.74	5	16	10	5	29	2.3	6.2
November	37.6	26.4	76	−18	70.0	3.6	47.7	.70	5	16	10	4	28	2.2	6.2
Autumn	49.6	....	93	−18	80.6	19.8	45.5	2.34	15	49	29	13	86	2.2	5.6
Year	49.1	.....	105	−29	79.2	19.7	48.4	14.95	81	163	140	56	340	2.6	6.3

NOTE.—The data for this table are derived from the meteorological summary furnished by J. J. Gilligan, U. S. signal officer, Denver, Colo.

TEMPERATURE.

From the physical nature of Colorado we must expect a low average temperature. The mean annual temperature at Denver is 49 degrees, about the same as at Chicago and Boston; but it is actually more extreme than this would indicate, for we also find that the lowest point the thermometer reached was 29 degrees below zero, and the highest point was 105 degrees. But these extremes are few and of short duration, and the records of the maximum and minimum temperature will be a better indication for this region than for many others. More often than this severe cold will come soft, balmy days in midwinter, when wraps are cast aside and the houses are thrown open in the genial sunshine.

In comparing the records of each season here with those of other parts of the country, we find that the average temperature is more equal here throughout the year. We have the winter temperature of

Saint Louis, the spring temperature only a little cooler than Washington, and the summer and autumn temperature of Boston.

Every one has perceived that the sensation of cold depends on many other things besides the temperature. The dry and rarefied air of this altitude, allowing the rays of the sun to pass through with but trifling loss of heat, renders the lowest temperature much more endurable than it would be in moister climates. If the sun be shining and the air still, it matters little how low the thermometer may fall, and zero weather will be pleasant and agreeable. This warmth of the sun is not shown in the meteorological tables, for the thermometers are set in the shade. By sun thermometers temperatures of 110 degrees and upwards are quite usual in winter, while 120 degrees has been observed in January. In the summer months the temperature in the sun usually ranges between 130 and 150 degrees. This heat would be difficult to endure if it were not for the same rarefied condition of the air which we have just found softening the effects of extreme cold. It gives a bracing, stimulating quality to the air in summer, and a fresh coolness to the slightest breeze, such as we never find in the low altitudes. Then, too, no matter how hot it may be in the sun, there is always a cool spot in the shade, and summer nights are rarely too warm for a blanket. This marked difference between sun and shade is the result of the lack of aqueous vapor in the air to become heated by the sun, for air of itself is diathermanous to the rays of the sun, letting them through without practically absorbing any of their heat. The great difference between day and night temperatures is shown in the large ranges of temperature, being for the mean daily range 30 degrees, the mean monthly range 53.7 degrees, and the mean annual range 131 degrees. For comparison, the same ranges of temperature at New Haven are, respectively, 16, 42, and 91 degrees.

Sudden changes of temperature are a peculiar feature of this climate. Without the sheltering influence of forests or mountain ranges on the north, something of the fierce cold is felt here of the blizzards or northers which, coming from the fields of ice and snow in the north, sweep with such deadly power over the plains farther east. They come suddenly, with little warning, chilling with their icy breath the soft, balmy air that precedes them, and causing the mercury to drop 40 degrees in half an hour, and from 80 degrees at noon to zero at night. But their violence soon carries them past, and the following day may be as pleasant as before the blizzard came. The changes from cold to heat are just as sudden and great, under the influence of the warm west wind, which comes down from the mountain sides extremely dry and electrical, driving the frost before it and absorbing the moisture of the ground and air. Under its influence the thermometer has risen, by actual observation, 40 degrees in thirty-five minutes, and after it had passed the thermometer has fallen 30 degrees in five minutes, so suddenly did its influence cease. This peculiar west wind will be discussed later.

From the foregoing we find that the peculiar features of temperature in Colorado are great extremes, great range, and sudden changes. Upon trees the effect of great extremes is not necessarily injurious, except in connection with a dry, porous soil, which, holding no moisture to form an icy protection, allows the frost to penetrate so deep as to reach the tender rootlets of a young tree. Frost has been found in the ground in Colorado 5 feet below the surface. The evil effects of this may be lessened by heaping snow around the foot of the tree, where it will melt and freeze and protect the ground. When snow can not be had water may be used. Late fall irrigation, just before freezing weather sets in, is therefore beneficial, from the coating of ice formed near the surface. Winter irrigation should also be practiced for the same reason.

The great range of temperature in Colorado is more injurious to trees than extreme cold, for all vegetation thrives best in equable climates. In winter the powerful heat of the midday sun in this thin air excites the flow of sap in a tree to such an extent that it does not recover its normal condition before it is frozen by the severe cold of the night. Trees are found injured on the south, but never on the north, side. To remedy this, the trunk is shaded by a board, or wrapped with matting, burlap, or straw. More trees perish during the warm, summer-like days of February than in the coldest weather. This great difference of temperature in sun and shade has also an unfavorable effect on trees in summer, retarding their growth and preventing the warm nights so beneficial to all vegetation.

It is a well-known fact that sudden thawing is more injurious to plants than freezing, and therefore the effects of cold are increased tenfold when followed by great warmth. For this reason sudden changes of temperature are the hardest for trees to endure. The hot blasts which come down from the mountains during severe cold often scorch the life from the tree, and the fierce blizzard from the north, which may suddenly appear on the warmest day in winter, chills it to the marrow.

We find little spring weather in Colorado, and the approach of summer is not gradual, as at lower elevations. Trees will be often tempted to open their buds in the warm sunshine of many days in March and April, only to be nipped by late frosts. For this reason fruits are difficult to raise, especially the early blossoming varieties.

On account of this peculiar winter weather, trees planted in autumn suffer more than those planted in spring, which have the benefit of a whole season to become accustomed to the new and peculiar conditions. Those trees succeed best here which form their terminal buds early in autumn, and make a definite annual growth, so that their tops may not be killed in the first frosts.

HUMIDITY.

Humidity, or the amount of moisture in the air, is a more powerful agency in climate than is generally recognized. It regulates light and heat, and checks evaporation from the earth by absorbing the heat and partly arresting the direct rays of the sun. It is the medium for the formation of dew, rain, and snow, and when examined in connection with temperature, gives the only true indication of the dryness of a climate.

Relative humidity, as given in the table, indicates the ratio between a given amount of vapor in the air and that which saturated air at the same temperature could contain. It enables us to form an idea of how near to saturation and therefore to possible precipitation the air has come. But it does not represent the actual amount of moisture contained in the air. This is dependent upon the temperature, for air when warm takes up more moisture than when cold, and the point of saturation may therefore represent more or less actual moisture in the air.

It has been found that "the expansion of air under the influence of heat increases its capacity for retaining invisible vapor from about half a grain in a cubic foot—the limit at zero, with the barometrical pressure at 30 inches—to 19.84 grains, the limit at 100° F." Therefore, in a cool climate like that of Colorado, the air will absorb and hold much less moisture than in a warmer one. Altitude has also a direct effect upon the amount of atmospheric moisture, for as the air becomes lighter and more rarefied, its capacity for moisture decreases, and in Colorado it will contain much less at the point of saturation for the same temperature than at sea-level. There often occur here what are popularly called "dry showers," in which the rain dries so quickly that its effect disappears almost immediately. The actual amount of moisture in the air or the number of grains in weight of vapor contained in a cubic foot of air is termed its absolute humidity, and is the only exact measure for comparison of atmospheric moisture in various climates. Knowing the relative humidity and the temperature and altitude of any place, the absolute humidity may be calculated. From the weather maps published by the Signal Service at Washington, we find it (the absolute humidity) to be 1.9 grains at Denver, 4 at Los Angeles, 3.5 at New York, and 3 at Boston.

From these figures it is readily seen that humidity has not necessarily direct connection with rain-fall, for at Denver the humidity is only half of what it is at Los Angeles, although the annual rain-fall in both places is about the same; at Los Angeles it is one-third greater than at Boston, though the rain-fall at the latter place is three times as much as at the former. We also find the humidity at Los Angeles to be greatest in summer, although the rain-fall is practically nothing. Air may be quite humid, but, if there are no cold currents, the vapor will not be precipitated in rain.

The small amount of moisture in the atmosphere of Colorado is indicated by the almost total absence of dew, fog, mist, and hoar-frost, by the scarcity of clouds, and by the rapid evaporation of rain and snow. It is also shown by the power in this climate of the solar rays to heat solid bodies exposed to them, while the neighboring air remains comparatively cool. Humidity is least on the open, unsettled plains, where there is nothing to prevent rapid evaporation, and it is greatest in the canyons and parks among the mountains, where the mosses, grasses, and trees retain the moisture in the soil, giving it out slowly and continuously to the air.

Trees depend upon the air for a portion of the moisture they receive, which, absorbed through the leaves, keeps up the free circulation necessary for their growth. Without moisture leaves can not take up from the air the carbonic acid and other gaseous products upon which they exist. Where this moisture is limited, more is demanded of the roots, and the relative proportion between them and the leaves must be increased. This therefore is one reason for the slow growth of trees here as compared with other places, and only those succeed well that have large and rapid root-growth, and especially those with a tap-root, or roots which naturally reach far down in the ground, where they find a greater supply of moisture. A tree in Colorado may have all the irrigation it can possibly need, but will never have the rich, luxuriant foliage seen along the Atlantic and Pacific coasts. During the spring and autumn rain-storms, already noticed, there is much humidity, as shown by mists and fogs, and under its influence the foliage of the trees always swells and expands, and starts into new growth. Moisture in the air will also benefit a tree through its roots, if enabled to reach them through a spongy, porous soil, or by cultivation with a spade or plow, which loosens the soil around the tree and allows the air to penetrate to a sufficient depth. This accounts for the fact that trees in cultivated ground will endure drought better than those not so favored. The porous nature of the soil in this region is therefore not so great a disadvantage as it might be, for it helps to carry to the roots whatever moisture the air may provide. Irrigation would be unnecessary if we had the moist atmosphere which enables farmers on the southern plains of Texas, for instance, to raise the richest crops without irrigation.

RAIN-FALL.

The rain-fall, or moisture precipitation, is the most important factor of any climate in relation to trees. It is also the most irregular of meteorological elements. But the records of thirteen years will show what may be accepted as the rule, though subject to many exceptions. The average annual rain-fall at Denver is 14.99 inches, and at Colorado Springs 15.87 inches. In comparison with this, at Los Angeles it is

18.25, at Chicago 37.34, and at New York 43.58 inches. The general distribution of rain-fall in this region is shown by the table, which gives the amounts for each month and season. In Colorado winter is the dry season and summer is the wet season; the driest months are January and February, and the rainiest are May and July. This is due to the altitude and inland position, for we find just the reverse at Los Angeles, where 10.43 inches, more than half the annual rain-fall there, falls in winter, and only 0.22 inches in summer. At New York the rain-fall is very evenly distributed throughout the year. A fact, not evident from the table, is that no rain falls, as a rule, in Colorado, between October and April. The storms that gather then are accompanied by such cold as to precipitate only snow, which is quickly melted and absorbed or evaporated. The heaviest fall of snow during the last ten years, about 2 feet deep, totally disappeared within a week. The large snow storms invariably come from the southeast, though a whirl of snow is generally driven before the fierce northers. This snow-fall being small and quickly disappearing in the warm sun and dry air, it has no opportunity to exert upon the air its cooling influence by increasing radiation and by hindering the warming of the ground.

The winter weather, as we have already found, extends into April and even May, and ends with a heavy snow or rain storm, lasting two or three days. Settled warm weather may then be depended on, but not before. The wet season begins generally about the first of July and remains six or eight weeks. During this season almost every day will bring its shower, which, coming in the afternoon, passes over before night, leaving the evening cool, fresh, and beautiful, or it will clear during the night, bringing most delicious mornings, with a wonderful clearness of atmosphere. The summer ends as it began, with a heavy rain-storm, late in August or early in September. This latter month is generally more or less rainy, but October and November bring the perfection of autumn weather, extending often to Christmas.

With so little of their chief means of support, it is not to be wondered at that the only trees growing spontaneously in Colorado are the narrow belts of Cottonwood that mark the course of the streams on the plains, and the groups of hardy Pines, Spruces, and Firs on the northern slopes of the mountains, or in the sheltered canyons. When these are destroyed nature finds it hard to renew the growth in any way, and only succeeds in the more favored localities. It may be accepted as a general truth that on these plains, and in many parts of the mountains, in most situations no tree can be expected to grow by the natural rain-fall. Irrigation is therefore a necessity, and as a system it has been brought to a high state of perfection during the past twenty years.

Water must be supplied to trees, not only in their growing season, but also during the dry winter months to aid in the small circulation of sap required to keep life in the tree during its long sleep, and to compensate for the evaporation from its bark. The tree needs much water during the dry, hot days of May and June, before the summer rains begin. During the wet season it will almost take care of itself, but when the rains cease in August the principal danger of the whole year comes, and as day follows day of hot, dry, scorching weather, the tree must be liberally supplied with moisture to take the place of that absorbed by the thirsty air.

This region does not receive the benefit it might from the rain-fall, on account of the deep, gravelly, porous soil, through which the rain sinks quickly, leaving but a small portion behind, a large part of which is soon taken up by the air, and but little remains for the tree.

EVAPORATION.

The evaporative power, or thirstiness, of the air is increased by high temperature, low humidity, low pressure, and high rate of motion. It is most powerful in summer in the sun and wind, and only slight in winter in shade and when the air is calm. In any place like Colorado, where are found many upturned faces of broken rocks and large uncovered areas of sand and gravel, evaporation and radiation will be much greater than in places where the surface is protected from sun and wind by vegetation. This is shown by the entire absence of dew on the plains and the rocky slopes of the mountains, and its formation when trees and lawns are planted.

Trees are injured by rapid evaporation, because it produces an unnatural activity in the roots and stem to supply the drain from the cells of the leaves and bark, and unless the tree has a large root-system and great vigor in all its functions, it will be unable to keep up the proper circulation. This is a reason for the fact already cited, that the trees which succeed best here are those of rapid, vigorous root growth, with a solid leaf structure. Evaporation is more rapid in winter, and therefore fall planting is objectionable. Imported trees always thrive best if they are cared for in a nursery for a year or two, until their roots, leaves, and bark become accustomed to the new conditions of climate.

WINDS.

The winds of this region, which, from the level character of most of its surface, are very constant and often of great velocity, have a strong influence upon the production of increased evaporation. In the daytime throughout the year the prevailing winds are from the south and southeast, while at night they are from the north. This is an advantage to trees, for the south and east winds, always more or less laden with moisture, come at a time when evaporation is most active, and tend to relieve its evil effects. The north wind, direct from the region of perpetual ice and snow, is the wind of blizzards and storms, and is the most injurious of all, from the sudden changes of temperature, already described, which it produces. The warm west or northwest winds, whose effect on temperature and evaporation, as already noticed, is so marked, are of such peculiar nature as to demand our especial examination. They are the same as the Chinook winds of Montana and the Foehn wind of Switzerland, and similar currents are found on the leeward sides of all extensive mountain ranges. Starting, it may be, from the surface of the Pacific, or in the warm valleys of the western slope, this aerial current is cooled and more or less completely deprived of its moisture while climbing the mountains; and in sliding rapidly down on the other side, it becomes gradually warmed by compression, amounting to six or seven degrees for each thousand feet, and arrives at the foot even warmer than it started. The direct effect of this higher temperature is to increase its capacity for holding moisture, and having no means in its descent of regaining what was lost in the cool, rarefied region above, it is intensely dry and parched, increasing evaporation to such an extent as to dry up small ponds and streams, and cause the snow to literally fade away. These winds are only noticed in cold weather, for when the air is already warm, the change in temperature on their account is not appreciable. Their effect on climate is to make the region they frequent of higher average winter temperature than in the center of the continent, as may be seen by the isothermal lines of any climatic map of the United States.

Their deleterious effect upon trees, besides the sudden changes of temperature, is more especially from their extreme dessicating power, which increases to an intense degree all the evils already described of rapid evaporation, acting on vegetation like fire. The barreness and somber appearance of the eastern slopes of the Rocky Mountains, as compared with the western, is caused partly by the blasting, scorching effect of these winds on many of the native trees, not vigorous enough to stand the sudden drain on their vital forces. They also, no doubt, play an important part in the treelessness of the western plains.

In general it is found that they harden and dry the fruit on the side exposed to them, blacken, char, and curl up the young and tender leaves, cut off the fragrance of odorous plants, and kill young sprouts in a few hours.

The winds of the greatest velocity in this region are from the north and northwest. The strongest wind that has ever occurred at Colorado Springs was from the northwest, in January, 1887. It began at about 8 o'clock in the morning, and gradually increasing in power, until at noon its velocity was 72 miles per hour, it died away entirely by 4 o'clock in the afternoon. But these extreme winds only come two or three times a year, and a velocity exceeding 40 miles per hour is very rare. The destructive tornadoes of lower elevations are unknown, and this region is not subject to the continuous gales found elsewhere. This is demonstrated by the average yearly wind-velocity shown by the table, which is only 6.3 miles per hour. And this figure does not properly show its effect, from the fact that the force of the wind, with any given velocity, is less in the light air of this altitude than at lower elevations. Another advantage here is that the strongest winds come in winter or early spring, when they have less effect on the leafless trees than they would have in summer, the windy season in many regions. It is very rare to find trees blown down, and seldom are branches torn off. The specially injurious effect of extreme winds upon trees in Colorado is from the gravel, or small sharp stones, caught up by them from the dry, loose, gravelly soil, and hurled with such force against the trunk and branches as to cut the bark, and give it the appearance of having been rubbed down by some rough substance. The bark of young trees has been often found scraped entirely off on the north and west sides after such a wind storm.

CLEARNESS OF THE SKIES.

Clearness of the skies is a direct result of the low humidity of this climate, and is one of the peculiar features of high altitude. Rapid radiation from the earth, the absence of moist currents in the air, the rarity of the atmosphere, all these prevent the formation of haze, mist, or clouds. The table gives the average number of days clear, fair, and cloudy, in each month, at Denver. In these records the observer counts the thinnest cloud, and many days are classed as cloudy or fair which would be generally termed fair or clear. The record of sunny days gives a better idea of the fine weather. At Denver the records also show that the average number of days in a year on which rain or snow fell is eighty-one, and the yearly average cloudiness in tenths of the sky is 2.6. During thirteen years the average number of days during the year on which the sun was not visible was three, and from October 30, 1879, to February 5, 1881, fifteen months, the sun was not obscured an entire day.

This clearness of the sky is one cause for the daily fluctuations of temperature already noted, and its effect on solar and terrestial radiation is very marked. Solar radiation at this high altitude is rapid soon after sunrise, because of the slight resistance which the dry, rarified air offers to the rays of the sun. While after sunset terrestial radiation is also rapid because there is no moist envelope shrouding the face of the earth to prevent the natural cooling of the dry ground. This is one cause for the late frosts which are so hurtful to trees and which farmers and cultivators never expect without a clear sky and dry air. Sunlight in Colorado is a nearer approach to white light than at the sea-level, and many persons find it necessary to wear blue or smoked glasses to protect their eyes against its effects.

Sunlight plays a very important part in the development of plants, and the various questions of the sun's rays, their quantity and action, their variations in the different hours and for different states of the sky, and the relative effects of their different elements, should be the subject of more research than they are. It may be thought that the clearness of the atmosphere in Colorado, bringing a superabundance of sunshine, is a great gain to all life. It is so to many conditions of human existence, but not to all, and under certain circumstances is directly injurious to vegetation. True it is that "Light is the source of life," but its very greatness and power require tempering, softening, and restraining, like fire and water. Sunlight and warmth start the machinery of a tree and produce the chemical combinations which are necessary to its life. Under its influences the mineral substances, drawn from the soil by its roots, are combined with the carbon and other matters received from the air through the leaves, and the resultants, carbon and oxygen, are produced, the former for the building up of the various parts of the tree and the latter by exhalation into the atmosphere, for the use of animal life. This machinery of the tree, under proper conditions, works as steadily and smoothly as the best regulated engine. But if the speed of an engine is increased too greatly there follows vibration, increased friction, a falling out of adjustment, and soon it becomes worn, broken, and useless. So with a tree, the rapid action produced by the bright sun and clear air may draw too greatly upon its means of subsistence, more or less limited in this dry region, and the tree, unable to keep up the supply, dies.

Thus we have found that trees in Colorado, especially in the section around Denver and Colorado Springs, suffer principally from extreme temperatures with sudden changes, and from lack of rain to supply the needed moisture for the roots. When water is supplied artificially by irrigation, they still suffer from insufficient humidity in the atmosphere to provide moisture for the leaves and stems, from rapid evaporation caused by the dryness and rarity of the atmosphere and the frequency of winds, and from the clearness of the sky, or lack of cloud and mist to intercept the dry, scorching rays of the sun, and to prevent the sudden changes of heat and cold. Truly, indeed, this is not a favorable climate for the growth of trees. But we have dwelt more particularly upon the injurious qualities of the climate. The conditions are not all unfavorable, and notwithstanding the many drawbacks trees will and do grow in Colorado and fulfill the objects for which they were created.

ADVICE TO TREE-PLANTERS.

We have already, from time to time, indicated some of the peculiar modes of treatment necessary for the successful growth of trees in this region, and a brief summary of these will be useful.

Those localities should be selected for planting, if there be a choice, which, by the configuration of the ground will be most protected. Among the mountains, this will be on the northern slopes, where the rays of the sun are least powerful and evaporation is least rapid. If possible the useful operation of plowing and cultivating the ground before planting should be performed. In this way the soil, besides being broken and softened, will be in much better condition to hold moisture and will require less irrigation than otherwise.

Choose those trees that are hardy, rapid, and vigorous in their growth. The following have been found to thrive well here when planted under the proper conditions: Soft or Silver Maple, Box-Elder or Ash-Leaved Maple, White Elm, Red Elm, White Ash, Black Walnut, Butternut, American Chestnut, Black or Yellow Locust, Honey Locust, American Linden or Bass-wood, Black Cherry, Black Birch, Red Oak, Pin Oak, Black Alder, Russian Mulberry, Mountain Ash, and the many varieties of Poplars and Willows.

Foreign conifers have not succeeded well as yet. From the nature of their foliage they seem to be less able to endure the hot sun and dry atmosphere than deciduous trees. Even the native conifers from the mountains are difficult to transplant to the plains on account of the increased dryness and exposure, and only succeed with the greatest care.

Plant in the spring, as early as possible, but so as to escape the hard frosts. If possible select trees which have grown in a nursery in this climate at least one year, in preference to trees brought from lower elevations and different conditions. In general it is better to buy small trees than attempt to raise from seed, which requires peculiar and careful treatment.

Dig large holes, much larger than are needed for the roots of the tree, cover the bottom of the hole with 6 inches of good top soil, mixed if possible with a little manure. Just before planting fill the hole with water. Plant the tree a little deeper than it was before and spread out the rootlets, sifting the dirt well around them and stamping it down solid. A mulching around the tree, if nothing more than of small stones, will be of much benefit to prevent the rapid drying of the ground. The irrigation ditch should run 2 or 3 feet from the tree, and a small branch ditch carried around a foot from the trunk, in which the water may stand and soak into the ground. In dry weather irrigate once a week, and during the rainy season only when the tree seems to need it. Irrigate in the autumn at such time as to freeze the soil around the tree, and two or three times in the latter part of winter when continued warm dry weather occurs. Remember that a tree may have too much water even in this dry climate. Snow heaped around the tree is beneficial. During the winter matting should be wrapped around the trunk to protect it from sun and wind.

With such treatment trees may be made to succeed well in this hard climate, and, though never so rapid and luxuriant in their growth as in lower elevations, they will amply repay the planter.

Nowhere are trees more needed than in this State, and nowhere should more efforts be made to obtain them. They should be planted on the plains, for shelter, and to hold the little moisture that falls. They should be planted on the mountains, to store up the rain-fall and keep the streams full. They should be planted everywhere, to bring to this barren region their beneficial influences.

With trees, as in all things, it is the first step that costs. Each growing tree tends to make its surroundings more adapted to its needs, and as trees are multiplied the climate must necessarily change. The currents of air will be checked and modified, preventing the high winds, sudden changes, and great extremes of temperature. The rain-fall will be retained longer in the ground, providing more moisture for the tree to carry through its leaves to the atmosphere and increasing the humidity. The air being moister, there will be more fogs and mists, and consequently more modified and less sunshine and less radiation. Evaporation will be also retarded by the mechanical obstruction of the branches. All these changes will increase the favorable conditions for the growth of trees, and while we have begun with the native Cottonwood, we will end with the less vigorous but far more useful sorts.

NOTE.—The planting of trees in the Rocky Mountain region has been confined mainly to ornamental and fruit trees, grown in towns and on farms and ranches. Some forest-tree planting has been done under the "timber-culture act," but the results so far are very meager.—B. E. F.

SNOW-SLIDES AND AVALANCHES—THEIR FORMATION AND PREVENTION.

By B. E. Fernow.

The question of protection against the disastrous effects of snow-slides and avalanches has been an important one for centuries in Switzerland, where it seems that not only special conditions favorable to their formation exist, but where, on account of the dense settlement of the mountainous region exposed to their course, their destructive effects are more intensely felt. So regularly, from period to period or year to year, do these avalanches occur in given localities, pursuing the same track down the mountain sides, that they have their names like the mountains themselves, or like the geysers, which may go off at any time, pouring forth their waters at irregular periods.

Note.—The dictionaries and encyclopedias do not seem to know the word "snow-slide," which is the term used in the Rocky Mountain region. The word "snow-slip" is used to denote "a large mass of snow, which slips down the side of a mountain and sometimes buries houses" (*Webster*), while "avalanche" is defined as a "large mass of snow, earth, and ice sliding or rolling down a mountain" (*Webster*), "or falling down a precipice" (*Ogilvie*). (To avale—to fall, descend, be lowered, old French *aval*—towards the valley.) There exists, therefore, no definite distinct idea that might belong to the one word or the other exclusively, and the words, have therefore been used as synonyms.

The question of the formation, dangers, and preventives of avalanches forms the subject-matter of a very interesting volume published at the instance of the Swiss agricultural department, in 1881, by I. Coaz, the general forest inspector of the Republic, whose personal observations and experiences for many years in the work of abating these dangers deserve special attention. While the conditions, atmospheric and geologic, of our Rocky Mountain region may not coincide or compare exactly with those prevailing in the Alps, yet a study of the causes and effects there observed through a long series of years and of the methods there employed to remove the causes and alleviate the effects of these dangers of mountain life may suggest a closer observation of our own conditions and the invention of expedients of protection better suited to our own needs. The accounts given on another page of this bulletin show that the phenomenon of avalanches is not unfrequent in the Rocky Mountains, and that their frequency and the extent of damage occasioned by them must be expected to increase as population and development there progress.

NOTE.—Mr. William N. Byers, C. E., a close observer and long resident of Colorado, says: "The main difference existing between our mountains and those of the Old World lies in the fact that there glaciers abound while we are free from them.' 'The great extent of plateau country causes the high temperature of the mountain ranges, and is the cause of the snow melting off yearly, in direct contrast to the mountains of Switzerland, thus causing a higher snow-line with us.

"Snow-slides are very common in Colorado, and most common in the San Juan near the main range. They occur every year, and, when snow falls to any extent, frequently, and many lives are lost." (Last year two hundred lives are reported to have been lost.)

March is said to be the most dangerous month in the San Juan, and, as an old miner expresses himself, "It is hard to say as to where it is safe to live in San Juan."

Commissioner of the Land Office, Williamson, in his report for 1885, states: "It may be noted also as another incident to this total destruction of timber along the canyons, that 'snow-slides' are of frequent occurrence in the denuded localities of the mining settlements, and that during the past winter some were attended with serious loss of life and property.

To show the not infrequent occurrence and disastrous effects of snow-slides and land-slides, the following newspaper clippings, taken within the last few years, have been here in part reprinted:

The well-known disaster at the Emma mine, a few years ago, will probably be remembered by all in Utah.

Helena. Mont., May 7, 1885.—The land-slide 1 mile east of Thompson's Falls, May 4, is not yet cleared. Water oozes from the ground 1,000 feet above the track. It is feared that the entire mountain side will be precipitated.

Silverton, Colo., December 22, 1885.—The first snow-slide of the winter occurred to-day, coming down the mountain into Minnesota Gulch. The slide struck the mouth of the Prodigal Son mine, filling the 85-foot shaft and burying two men who were working at the bottom. The snow was packed so tightly that it was found to be impossible to move the bucket. The news of the accident was a great surprise, as it was not supposed sufficient snow had fallen on the mountain to make a slide that would cause damage.

Ouray, Colo., January 17, 1886.—Ruby Trust's cabin, on Mount Sneffels, was carried away this morning by a snow-slide, burying six men.

Robinson, Colo., January 25, 1886.—A snow-slide occurred near Summit City this afternoon, which buried a team and two men.

Aspen, Colo., January 25, 1886.—A snow-slide of considerable dimensions passed over the Jessie mine, on Aspen Mountain, at noon to-day, demolishing the machinery and ruining the buildings. Fortunately no lives were lost.

Durango, Colo., January 26, 1887.—Leonard Sutton, who has been working in the Silver Lake basin in the La Plata mine, reached Durango last night with an account of a slide which wrecked the cabin at the Daylight mine, Tuesday last.

Gunnison, Colo., January 26, 1886.—A snow-slide occurred on Sunday and carried away the cabin of the Excelsior mine, located in Poverty Gulch near Crested Butte.

Ouray, Colo., January 15, 1887.—Marshall basin was visited by another snow-slide yesterday.

Gunnison, Colo., January 18, 1886.—W. J. Fine, S. F. Winters, and Will Turner, returning from a surveying party to Spring Creek this evening, had a narrow escape. When directly opposite the mouth of Dead Man's Gulch, they noticed a snow-slide coming down the mountain. The edge of the slide caught three men and horses.

Aspen, Colo., January 20, 1886.—Numerous snow-slides are reported here. A snow-slide of gigantic proportions passed over the Aspen mines. The engine-house was crushed in, and the engine and boiler buried, and several men killed. Half an hour later another slide occurred in an adjoining gulch, which passed over the Last Chance mine, but without damaging effect. At 5.30 the fire-bell announced the occurrence of another slide, and investigation revealed that two ore-wagons, mules, and drivers had been buried in another slide near the Late Acquisition.

Another slide occurred on Castle Creek last night which caused the closing down of the electric-light works. The seven men who started for Maroon Pass yesterday morning have not yet been heard from. A slide between here and Ashcroft last evening took away a shanty, in which a man and woman were known to have lived.

Just before dark last night three teams and four men were caught on Aspen Mountain near the Last Chance mine. They were found to-day uninjured, having been imprisoned nineteen hours.

Aspen, Colo., January 21, 1886.—The results of the terrible snow-slides of Tuesday continue to arrive. (Accounts of accidents are given.) During the past three days twenty-seven snow-slides have occurred in the neighborhood of Maroon Pass. This evening a miner from Conundrum stated that a fearful slide occurred this afternoon in exactly the same spot where occurred the fatal slide two years ago in which several men were killed.

Ouray, Colo., January 21, 1886.—George Boss, mail-carrier, reported a large slide on the Dutton mine, in which four miners were swept away and the new plant of machinery and houses a total wreck. The Gilpin County Mining Company's building and George Porter's store at Sneffels are all gone. The loss of life and property will be large.

Leadville, Colo., January 21, 1886.—About 10 this morning a slide occurred on the Blue River Branch of the Rio Grande near Chalk ranch. The track covered at least 10 feet.

Gunnison, Colo., January 26, 1886.—News has just been received here of two snow-slides which occurred yesterday morning, in the northern end of this county, in which five men lost their lives. The Excelsior mine in Poverty Gulch, 8 miles north of Crested Butte, was the scene of the horrors. The second slide occurred on White House Mountain, in Crystal Basin. Many small slides and narrow escapes are also reported in different sections.

In the following, therefore, that which appeared worth noting in the volume referred to has been presented. As far as could be ascertained no literature on the subject is extant in this country.

NATURE OF SNOW.

Snow is of different qualities according to the temperature of the atmosphere, and on its quality depends the form, the manner of formation, and the progress of snow-slides and avalanches.

The temperature at which snow may fall (in the Alps) ranges between 40° and 12° Fahrenheit. At low temperatures snow falls rarely, and then only in fine needle-like crystals. With a north wind it snows mostly at a temperature below, with a south wind above, the freezing point. The snow-fall at temperatures above zero is to be explained by the existence of a lower temperature in the higher strata of the atmosphere where the snow forms. During a continuous snow-fall, and especially if the wind changes, the temperature, and with it the form of the snow, may change considerably.

Snow falling at low temperatures is dry and composed of small flakes, because the dry crystals do not hang to each other; such snow does not hang on or ball easily nor does it make good sleighing. It lies so loose that it is easily moved by the wind, like sand, and causes snow-drifts, while the wet snow falling at higher temperatures, which has begun to thaw and contains much air inclosed, packs tight and shrinks quickly.

The first snows of the season soon melt away, except in the highest altitudes, because the temperature of the soil and atmosphere are still too high for it to remain. As soon as the soil is cooled down to freezing point the snow remains. If the temperature rises above freezing point the snow begins to thaw superficially, part of the water evaporates, part seeps through the snow and saturates it with water, or else the water penetrates to the soil and softens this gradually. The snow thus shrinks and settles until the temperature sinks again to freezing point, when snow and water freeze together.

Thawing, evaporation, settling of the snow, depend on temperature, the relative humidity of atmosphere, clear or cloudy sky, and on the direction of the winds.

It would be supposed that winters of much snow-fall would bring the greatest number of snow-slides. This is not the case in the Alps, on account of the dry southern wind (Foehn) prevailing in such winters, which evaporates with great rapidity much of the snow. If, in addition, the soil was not frozen before the snow-fall and is capable of taking up the snow water, snow-slides are made still less frequent.

NOTE.—The existence of a "Fœhn" in our own mountain region is perhaps interesting enough to justify the following extract from a paper by Prof. W. M. Davis, of Harvard, especially as it may suggest explanations of other climatic characteristics of the Rocky Mountain region:

"First in Switzerland and afterwards in other mountainous countries, the attention of meteorologists was called to the occurrence, especially in winter time, of a warm, or even hot, dry wind, blowing briskly down the valleys from the high, cold passes. The Swiss name for such a wind is "Fœhn," said to be derived from the old Latin name Favonius. Various local names are used in other countries, but with the present understanding of the origin of the wind, all examples of it may be included under the Swiss term, which has now become of generic value. When the Fœhn blows, it is common to see a bank of dark clouds over the pass at the head of the valley from which the wind descends. Under its effects the snow-fields melt away, and the streams rise in freshets.

"The origin of the wind should be looked for, not on the farther side of the mountains, whence it blows, but in the direction towards which it flows. Its warmth and dryness were first properly, but, as will be seen, not fully, explained as follows: When a current of air, moving on its oblique path towards a center of low pressure, encounters a transverse mountain range, and is forced to ascend over it, the air expands and is thereby cooled; in consequence of the cooling, its vapor is condensed into cloud, and soon begins to fall as rain, so that on reaching the summit of the range the air contains less vapor, although it is very moist and cloudy; its fall in temperature has decreased its absolute humidity, while increasing its relative humidity. It must be further noted that on account of the release of the energy before employed in maintaining the rain in the state of vapor, the cooling of the ascending current is considerably retarded; the rate of cooling in an ascending mass of saturated air being only from one-third to one-half as fast as in non-saturated air. As soon as the current begins its descent on the leeward slope of the range, it is warmed by compression, but until all its cloud is evaporated it warms as slowly as it cooled before; however, by reason of having lost some vapor that fell on the windward slope as rain, the cloud mass to be evaporated in descent is less than the total cloud mass formed in ascent; the descending current soon becomes clear, and then warms at the relatively rapid rate proper to non-saturated air, and as a consequence of warming faster than it cooled it must reach the valley bottom as a warmer wind than it was on starting to ascend the other side of the mountains. Having lost some of its humidity and gained in temperature, it must be relatively dry; it is a Fœhn.

"Only one element remains to be added to the explanation, but it is a significant one. Thus far the production of the Fœhn depends on the evolution of 'latent heat,' while the wind is rising and raining on the farther side of the range; now it appears from more precise observations that the winter Fœhn is often felt in the northern valleys of the Alps a day, or even more, before any rain falls on the southern slope; and therefore, although the rain is an aid when it begins, it must in these cases be preceded by some other cause not dependent on the ascent of air towards the passes and the condensation of vapor on its way. The solution of the difficulty is as follows: The average rate of variation of temperature in the atmosphere is closely one degree Fahrenheit to 300 feet of descent. Inasmuch as the air is less active than the ground in changing its temperature, this rate will be increased in the summer season and decreased in the winter; in winter the rise of temperature encountered in descending through the air is generally less than the gain of temperature given to a descending mass of air by reason of its compression. If at such a time the air in a valley be withdrawn by flowing away in answer to the call of an area of low pressure, and its place be taken by air descending from the passes to windward, this fact of descent will require that the new supply of air shall be warmer than that which has moved away; it is necessarily very dry, because it gains capacity for vapor as its temperature rises, without gaining the vapor to satisfy its capacity. This is the first cause of the Fœhn, and explains in good part why it is more pronounced in winter than in summer. When the wind over the pass is well established, it may be joined by currents of air rising from the further slope; these soon become cloudy and yield rain, and then the second cause of the Fœhn is in operation, as already explained.

"The Chinook wind of the northwest, along the eastern foot of the Cordilleran ranges, is described by G. M. Dawson as 'a strong westerly wind becoming at times almost a gale. It is extremely dry, and, as compared with the general winter temperature, warm. Such winds occur at regular intervals during the winter, and are also not infrequent in the summer; but being cool as compared with the average summer temperature, are in consequence then not commonly recognized by the same name. When the ground is covered with snow the effect of the winds in its removal is marvelous, as, owing to the extremely dessicated condition of the air, the snow may be said to vanish rather than to melt, the moisture being licked up as fast as it is produced.' (Science, 1886, vii, 33).

"Professor Loomis notes the following case of rapid temperature changes at Denver, Colo., on the plains just east of the front range of the Rocky Mountains: 'An area of low pressure passed over San Francisco January 14, about 4 p. m. During the following night the center passed near Salt Lake City, and at 4 p. m., January 15, the center was near Leavenworth, having traveled about 1,400 miles in twenty-four hours. It was this storm which brought the air from the west side of the Rocky Mountains over to Denver. The vapor contained in this air would be mostly precipitated on the west side of the Rocky Mountains so that it would descend on the east side deprived of its moisture and with a temperature above that which prevailed in the Salt Lake basin, on account of the latent heat liberated in the condensation of the vapor. After the center of low pressure passed Denver, the northeast wind returned and brought back the cold air which had constantly prevailed at stations not very distant. Thus we see that in winter, during periods of extreme cold on the east side of the Rocky Mountains, when the temperature at Denver sometimes sinks more than 20° below zero, there prevails in the Salt Lake basin an average temperature of about 30°; and when by changes of atmospheric pressure this air is carried over the mountains it may reach Denver with a temperature of 50°, resulting from a precipitation of vapor on the mountains. We thus find a mass of air having a temperature of + 50° in close proximity to a mass having a temperature of −20°, and by the movements of the atmosphere attending the progress of a great storm these different masses of air may be brought successively over the same station, causing a change of temperature of 50° in a single hour.'

"The following tables present numerical accounts of these changes from the same authority:

Temperature and relative humidity, January, 1875.

Date.	Hour (Washington time).	Salt Lake.		Cheyenne.		Denver.		Pike's Peak.		North Platte.	
		Temperature.	Relative humidity.	Temperature.	Relative humidity.	Temperature.	Relative humidity.	Temperature.	Relative humidity.	Temperature.	Relative humidity.
		°	*Pr. ct.*	°	*Pr. ct.*	°	*Pr. ct.*	°	*Pr. ct.*	°	*Pr. ct.*
January 14.....	7.35	34	61	−11	76	−14	100	1	100	−13	74
	4.35	43	50	− 1	68	− 4	64	8	100	− 6	61
	11.00	43	50	24	60	1	71	5	100	−11	76
January 15.....	7.35	32	84	28	67	43	21	6	100	− 8	79
	4.35	26	52	5	75	10	17	12	100	− 1	68
	11.00	23	73	− 6	61	13	44	10	100	− 4	64

"Salt Lake, at the western foot of the Wahsatch range, in the Great Basin, is constantly rather warm, and of ordinary humidity. Pike's Peak is cold and constantly at its dew point. North Platte, on the plains east of the mountains, is much colder and distinctly drier. Denver and Cheyenne are much alike in changes of temperature, as these stations are about equally distant from the eastern foot of the mountains; but Denver shows much the greater decrease in relative humidity, perhaps because the range west of this station is higher than farther north. The second table shows in greater detail how violent the changes of temperature were at Denver and how completely they accorded with changes in the wind:

Temperature and wind, Denver, January 14, 15, 1875.

Date.	Hour.	Temperature.	Wind.
		°	
January 14	2.43 p. m.	− 4	NE.
	9.00 p. m.	+ 1	NE.
	9.15 p. m.	20	SW.
	9.20 p. m.	27	SW.
	9.30 p. m.	36	SW.
	9.35 p. m.	40	SW.
January 15	5.43 a. m.	43	SW.
	10.30 a. m.	52	SW.
	12.30 p. m.	4	NE.
	2.43 p. m.	+10	....

"An observer who was considered perfectly reliable says that between 11 a. m. and noon the thermometer fell from 58 to 22 (that is, 36°) in five minutes." (Amer. Journ. Science, 1875, x, 12; 1880, xxii, 13, 14.)

Any one who wishes to understand the climate of the Rocky Mountains will also do well to read an excellent paper on the Chinook winds by Prof. M. W. Harrington in the American Meteorological Journal for 1887; from which we cite only a few points:

"The dry character of these winds is usually seen only to the eastward of the mountains. In western Oregon and Washington they are moist, and the same is true of the western slopes of Idaho and Montana. But as the name is more generally used east of the mountains, where the idea of dryness is a fundamental one, the Chinooks are defined as warm, dry westerly or northerly winds occurring on the eastern slopes of the mountains of the Northwest, beginning at any hour of the day and continuing from a few hours to several days. Their effects are felt at least as far as 500 miles east of the divide. On the arrival of the Chinook the winter appears to yield, the air becomes mild and spring-like. This effect appears in the winter isotherms, making the average winter temperature on the plains east of the Rocky Mountains in the great interior basin and the narrower interior valleys to the north, notwithstanding their continental position and high elevation, actually higher than on the same latitudes east of the Mississippi River; yet at the same time the range of temperature for the northwestern plain and the changes more sudden and severe. These changes are injurious to tree life, and in them can be found one reason for the difference between the eastern and western slopes of the mountains. The eastern slopes are bare, rugged, and somber; the western heavily clothed with timber. These trees, largely conifers, which can endure without injury very low temperatures, are very sensitive to extreme dryness. The dry air injures the foliage, and when accompanied by wind may kill the cambium on the windward side of the trunk, thus permanently injuring and in time destroying the tree. The Chinooks have probably played an important part in the treelessness of the Western plains and interior basins."

MOVEMENT OF THE SNOW, FORMATION OF AVALANCHES.

On the plain the snow moves only by settling and by drifting. On an incline, even if only slight, there is a side movement, following the law of gravity and depending in its amount on the angle of inclination, configuration, and especially cover of the ground, and also on the nature and amount of the snow. If the snow is frozen to the soil, it can not of course move. Otherwise, even if the conditions are not favorable to motion, and a movement may be hardly noticeable, yet it exists within the mass, and becomes apparent by the formation of horizontal rills on the surface of the snow. This movement and the pressure due to it is capable of displacing buildings without much injuring them. The more favorable the conditions are for motion the greater becomes this movement, until at last a slide occurs, moving in larger or smaller masses, more or less rapidly over the incline.

According to the temperature or the nature of the snow dependent thereon, the form and effect of the avalanche vary.

If in cold temperature a large amount of dry snow falls on a steep, deforested mountain side, it behaves like a sand-heap, the particles getting into motion for lack of stability in the mass, and moving forward, the mass carries with it any other masses of snow that are in its way. The heavy particles arrange themselves towards the soil, the finer particles forming a cloud of snow bursting into the air and like dust settling down only gradually.

This falling cloud, which obscures the mountain view for some time, compresses the air to such an extent that like a cyclone it precedes the avalanche, followed and pressed on by the latter in hasty flight and exerting an enormous pressure, often over great distances, sometimes 2 or 3 miles beyond the actual course of the avalanche.

The destruction, which is due to the snow-masses of such a slide, are insignificant in comparison to those of the compressed air-current, since the snow is light, and by the fall dispersed and scattered and may pass through a thinly stocked forest without doing much damage. One of such air currents preceding an avalanche is reported to have carried a full-grown larch tree bodily over the tower of a prison, lodging it 300 yards beyond, and to have laid low timber drift 200 tc 300 feet beyond the avalanche. Such slides are called *dust*, or *powder avalanches.* They usually occur during a heavy snow-fall, and are but rarely occasioned by winds afterwards, if perchance the snow has been able to preserve its loose and dry condition and could keep in position long enough. It seems that most of the snow-slides of the Rocky Mountains are of this nature.

If the snow falls when the temperature is not low, it is wet, heavy and compact, and hangs to the soil closely. If not much snow fell, it remains lying undisturbed, provided the soil is not wet or slippery and the ground not very steep. The larger the mass of snow and the warmer the temperature, the greater is the danger of a movement of the mass in itself and a consequent slide. In such a slide the snow remains compact and does not disperse unless falling over precipices. It does not therefore exert much pressure upon the air, flows more like a snow-stream, now sliding and now rolling over and balling together. Its velocity in spite of its great weight, on account of its friction against all obstacles on its road, is much less than that of a dust-slide and its effects reach over a smaller space. These may be called *ground slides,* or true slides.

Lastly, a third kind of avalanche is mentioned, with which we have nothing to do in this country, except perhaps in Alaska and Nevada. These are the glacier avalanches, which are formed when large masses of the glacier disconnect themselves from the main flow, and falling over a precipice break up into something like a dust avalanche.

MECHANICAL AND ATMOSPHERIC CONDITIONS.

Apart from the nature of the snow the following conditions are of moment in the formation of avalanches:

First, the geological formation of the mountains: Compact rock-formations are less favorable to formation of avalanches, especially ground-slides, than stratified rocks. The latter offer more opportunity on the side of the dip than on the side of the outcropping (head). Granite and granitic gneiss mountains are therefore less liable to avalanches than slates, limestone, Flysch*—only often the angle of inclination on the dip is less than on the head, when a reverse of favorable conditions occurs, but the slides on the head side usually do not fall into places where much damage can be anticipated.

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* A formation composed of alternating layers of black slate and sandstone.

Rocks easily disintegrated, like the slates, Flysch, etc., are more favorable to the formation of slides than solid rock.

Very dangerous are steep, stratified rock faces, from which spring and seepage water oozes out, which keeps the surface moist and slippery, or else when frozen gives no chance for the snow to lie.

On a rocky and very steep mountain side the snow when reaching a certain depth must slide for lack of internal coherence, especially when dry. During a continual snow-fall several slides may fall from the same place, but they are mostly of small dimensions and little effect.

If the rock has a soil over it without vegetation, the formation of slides is dependent in the first place on the degree of steepness. Yet other factors, as the height of the snow, the height of the mountain wall, etc., are of such influence that the angle of elevation may not be made a mathematical expression of the danger.

If the foot of the snow-wall is washed by a brook, or if a spring or other circumstance disturbs the continuity of the snow-masses, the formation of avalanches is favored; it is therefore dangerous in places liable to avalanches to open a track or even to wade through the snow.

A declivity which offers varying angles, or is broken by occasional steps or terraces, offers so many points of support to the snow-masses, that avalanches are less liable to occur; roads, ditches, or other artificial barriers to an even descent, offer also such points of support.

Most important is the soil-cover. The more and the larger the loose rocks, the more in the line of the horizontal they are placed, the more hold and support has the snow.

Vegetation has a varying effect upon the formation of slides, according to the kind of plants that occupy the ground and their size. A grass cover or turf is favorable to the sliding of the snow. It has been observed in the mountain meadows, where the hay is made every second year, that slides are less frequent the winter after the grass is cut.

Low shrubs and tree-forms offer a better support to the snow, unless their stems are, as in the case of the Mountain Alder, so elastic that after being pressed down they exert a pressure against the snow which tends to interrupt the coherence of the mass, when, with the aid of wind or additional snow-fall, the snow may be set in motion.

High timber affords the best protection against snow-slides, and if the mountaineer had not in his ignorance removed and destroyed this protector, many dangers of a mountain home would be avoided. The importance of the forest in this respect was recognized in the Alps centuries ago, and wherever "ban" forests were maintained, immunity from avalanches to the extent of the forest has been secured. An interesting account is given of the ban forest of Urseren, which was reserved by the community as early as the year 1397, and of the constant fight which was necessary against reckless advisers to keep it intact, until now the beneficial effect is fully recognized, and reforestations have been begun everywhere under the protecting walls or other safety-works wherever the danger of avalanches exists.

Yet even timber-forest is not always absolute protection against avalanches; since the place of incipient formation of the slide may lie above timber-line. Such avalanches, formed above the forest line, if small, first break a wedge into the forest below them, but by repeated action the wedge is enlarged and gradually a road broken through the forest. Large avalanches break, even in their first attempt, through the best rooted full-grown forest of entire mountain sides, hurling earth, rock, and timber into the valley below.

Water, the great mover of the earth, is an active agent in the formation of avalanches. Not only the spring and seepage water, but also rain and melting snow-water exert their influence. Ground-slides (in the Alps) occur mostly in warm weather in the spring, when the snow melts. Then the snow settles and becomes more compact, has a greater specific weight, and therefore more tendency to slide; the snow water penetrates through to the soil, and if the soil is not frozen, saturates it and then seeks to flow off between soil and snow, by which the hold of the snow on the soil is loosened, the latter made slippery, and the sliding facilitated. How soon this influence of water becomes active depends on how soon the soil is filled up with water, and this again on the kind of soil and subsoil.

Clay soils soon fill up in their upper strata and the snow-water sooner begins a superficial flow; a penetrable soil on the contrary with penetrable subsoil does not attain saturation at all and the danger is avoided. If the soil is frozen, the water can not penetrate at all and the sliding takes place the sooner. Rain of course adds to the water which loosens the snow.

Configuration, as has been said, may prevent formation of avalanches by presenting a number of points of support. Yet where there are sink-holes or troughs in which the snow accumulates, the melting snow-water collects below the snow and loosens the masses, which may thunder into the valley, following the course of the ravine.

Lastly, even an exterior pressure or disturbance may loosen the masses. A stone or an icicle falling, or snow dropping from the branches of a tree, when accompanied by strong wind, is liable to start the snow. So can one avalanche, by the concussion of the air which it produces, start others in its neighborhood. It has also been frequently observed that a sound, as of a gun, of church bells, of an explosion from mines, etc., may start the snow. This has given rise to the proposal to start the slides by shotguns before they are likely to become dangerous.

On the other hand, sometimes in the stillest weather the danger may be greatest, as the snow falling during such weather accumulates to large amount before it breaks loose; while in stormy weather smaller masses are constantly set in motion and come to strand on the terraces, etc., thus reducing the danger.

Some special conditions for the formation of slides exist, when days with a temperature above freezing which thaws the surface of the snow, alternate with cold nights when the surface freezes together. If fresh snow falls on such a surface, it is most liable to form into an avalanche, and sometimes if a heavy snow-fall occurs, it may break through the crust and carry the lower masses with it. This kind of slide occurs mostly on southern exposures.

As regards season and periodicity of slides the greatest diversity exists. New tracks are opened every year, while in other places the old tracks become scenes of disaster in varying intervals, some yearly, some every half or every full century. It depends of course on the amount of snow fallen, in connection with weather conditions, especially the direction and force of winds. The most regular falls occur in spring during time of thaws.

In wind-still weather and warm sunshine, the time of fall occurs in the first hours of the afternoon, yet if a warm wind blows any time of day or night, the avalanches may start.

PROGRESS OF AVALANCHES.

The ground-slides follow more or less the contour of the ground, like running water. Usually the masses start sliding, later on they roll over when passing over steeper and rocky ground, and in *rills* and *funnels* they are compressed and compacted.

As in a stream of water, the greatest velocity lies in the center of the slide, where in a straight track the largest mass and the least friction exists. If turned from the straight track the force is greatest on the outer curve, where trees, turf, soil, and rocks are torn up and swept away together.

Dust-slides occur most frequently during snow-falls at low temperatures, especially in windy weather. They occur oftener in clear weather than when the sky is clouded.

RESCUE OF PERSONS BURIED BY AVALANCHES.

After pointing out the different localities which are exposed to avalanches in the Alps, and giving an account of some special cases of disasters, which forms most interesting and instructive reading, a chapter is devoted to the measures to be taken in saving men lost in snow-slides. The procedure is somewhat like the following:

First look over the surface of the snow, where the slide has come to rest, after signs of the unfortunate victims. If no parts of the body are visible outside, determine, according to the location and the track which the slide took, the place where most probably the entombed lie. Then let the rescuers take position in line, and with the handles of shovels, or with poles, push into the snow every foot or so, progressing forward as they do so. If a human body is touched, the elasticity will be noted; also, the poles pushed down around the body will sink deeper, for the entombed usually do not lie on the ground, but are imbedded in the snow. Accounts are given of men who have been imbedded for fourteen, nineteen, and twenty-four hours, and one case, in which a woman was found living after one hundred hours, is almost incredible.

The work of rescue should, therefore, never be speedily abandoned.

Death usually occurs either through bodily injuries or through suffocation, mostly the latter. The more or less rapid effect of suffocation depends on the density of the snow and the position into which the body comes to lie. Naturally, if the head lies downward, and is packed into compact snow, death must occur sooner than when the body gets into an erect position with less snow pressing upon head and breast.

If the face comes near a hollow space in the snow, and breathing is facilitated, the entombed can live in spite of the cold for a long time, and can be saved or even save himself; for the heat of the body thaws the snow gradually, around breast and abdomen first, around legs and arms more slowly, because these parts are more distant from the source of warmth.

From this some rules for the conduct of those who can not escape the slide may be inferred, namely, that they should try to preserve an erect position in the fall, and to keep the arms near the body, so that the arms may sooner be released by thawing and become useful in the rescue.

When the slide comes to rest the entombed at first feels a pressure; this is soon relieved, after a few seconds, by the partial freezing of the snow-masses and a consequent contraction.

The entombed hear and understand any noise or voice above them, but their own voice can not be heard above; this probably because the sound waves can not sufficiently develop in strength in the surrounding snow.

The treatment of the rescued depends of course on the circumstances of the case. Resuscitation is often possible, even if the rescued is apparently dead. In all cases the first duty of the rescuers, when they discover the body in the snow, is to provide means for breathing by opening up a channel to the mouth. If the rescued is apparently dead respiration must first be restored. This is done by placing the body on the belly, supporting the front of the head lightly, pressing evenly and slowly with flat hands upon the sides of the breast, rolling the body over on the side and a little further and back on its belly, repeating the pressure on the sides; this movement should be repeated sixteen to twenty times per minute.

Another mode is to place the body in sitting posture, supporting the head, grasping from behind the two forearms in the middle and moving them forward and upward, until they touch both sides of the head, then move them down and press with them against the sides of the breast, repeating the process sixteen to twenty times a minute.

This treatment should be continued for twenty to thirty minutes if necessary, while rubbing the patient vigorously with flannel or woolen cloth, in the direction from feet and hands toward the body.

Besides absence of respiration, cold and hunger may add to the causes of asphyxia. In such cases, too, artificial respiration is first to be supplied. The warming should be only gradual, never in a warm room, or with heated bottles, but always by rubbing.

When the body becomes warm the danger in nose, ears, hands and feet of a surplus of blood or of impeded blood-circulation is avoided by cold compresses, by rubbing with snow, and elevating the affected parts.

As soon as respiration is restored small doses of coffee, tea, or brandy should be given.

MEASURES OF PROTECTION.

The damage done by avalanches, besides the immediate one of destroying life and property and devastating meadows and agricultural lands, lies in the tearing up of tracks in the ground in the shape of rills and furrows, which may become the beginnings of dangerous torrents and land-slides.

Those slides which fall into wild mountain gulches do damage by tearing down the decomposed rock and stones, which high water may carry to the valley and over fertile fields.

Measures of protection against avalanches and snow-slides have been applied, of course, by the dwellers of the mountains since their occupancy began. These consisted, where the ground permitted, in placing the buildings into the mountain side, when the avalanche would shoot over the building, or by building safety places, where to retreat in case of danger. Probably, when by deforestation the danger from avalanches had increased, a protecting wall or a stone or dirt heap was erected, close above the houses which were to be protected, with an acute angle towards the mountain top and with walls entering to right and left; such protective walls sometimes included a number of houses.

On the mountain roads galleries were built, either cut into the living rock, or with stone or timber, over which the snow masses would slide.

These measures were intended to prevent the damage from avalanches and slides, but to prevent their origin and their start measures were also adopted early in this century. Such measures were the making of ditches in horizontal lines, to prevent the snow from sliding, or of terraces, and the proper preservation of the forest growth.

But only since 1867 has a systematic treatment of the avalanches been begun under technical direction. Since then, up to the year 1881, thirty-four tracks of avalanches or snow-slides have been systematically secured with perfect success.

In undertaking such work, it is first necessary to establish from testimony the uppermost point from which the avalance has been observed to start, which testimony, however, must be verified by a careful study of the natural conditions of the locality. Usually the place of beginning lies higher up than observed. If the start lies on extensive, steep, rocky faces, there is no use in trying to secure it; if there are only interrupted walls and rock portions, or if a ravine form the starting place, securing is possible, and the question then simply is, whether the cost of doing so is in proportion to the benefit to be derived.

The works consist of walls or woodwork, or a combination of both. Ditches are not without influence, but are by no means as effective as wall and woodwork, and present, besides, several objections; they are collectors of water, which is liable to carry away the earth work; they are soon filled up or trodden down; similar objections exist to terraces.

The choice of stone or wood for safety works depends mainly on the costliness of either. Above the timber line stone would of course be preferable, below the line it is employed only where reforestation, and, therefore, temporary constructions are not possible.

Wood structures consist of rows of pile work, for which of course the most durable wood obtainable in the region is used. Split wood is better than round, which latter does not hold the snow as well. The piles are usually made 4½ to 5 feet long, and have a diameter of 5 to 6 inches. Preserving processes, charring, etc., are unnecessary in the altitudes where this work is to stand. The posts are pointed at one end, and driven with a wooden wedge, so as not to split them, if possible, 2½ feet into the ground, perpendicularly to the horizontal plane, and secured with stones. They should not be above ground more than 3 feet, and on thin soil not as much.

The intervals between the piles should be 2 feet. It is not necessary to connect them by wicker work, as the snow does not slide through the piles; but where the ground is thin, or very dry, or very steep, or otherwise lacking in hold, such wicker work may be made of branches to connect, and thus to strengthen the piles. The two end piles must be especially secured. The length of the rows of piles and their distance from each other depend upon the configuration and the angles of inclination of the ground.

The choice of the place where the row of piles is to be put is of importance. The work is begun at the top or starting place of the avalanche and progresses downwards. The piles must be driven in the horizontal line, so that the pressure of the snow will be evenly distributed over the whole line. They are also to be placed where a change of fall (angle of inclination) from a less steep into a steeper incline occurs. If no natural terraces are found, such may be made by cutting into the ground above the piles, making a terrace of 2 feet in the side of the mountain. The ground thus removed is placed on the lower side of the piles and covered with turf.

Where piles can not be driven "snow-bridges" are constructed Where narrow rills or runs are to be protected a tree is thrown across and secured at its ends against other trees, or by posts, or placed upon trestles, if necessary, supported in the middle by posts. Over this tree are placed sticks, with a slight inclination to the mountain side, somewhat in the shape of a corduroy bridge, and fastened with wooden nails to the tree and secured by stones on the ground, if possible.

The retaining works of stone are the strongest, most lasting, and are possible everywhere, but also the most expensive. For a foundation a space of about 3 feet is leveled, with a slight inclination into the mountain side, as if cutting out a road; the base must be natural, not made, soil. The proper making of this foundation-base is of the highest importance. The height of the wall must be 3 feet above the ground on the upper side; the steeper the ground, therefore, the higher necessarily becomes the wall work. Simple dry walls are all that is needed, which, in addition to being cheaper, permit rain and snow water to seep through.

Especially the ends of the wall must be well secured, and the use of cement in this part of the wall is recommended. The roof is made of large slabs or, in their absence, of sods.

The length of walls, as of pile rows, depends on the configuration of the soil. The distance of the walls from each other may be greater than with wood-work.

There have also been used iron rods let into the rock and covered with wood-work.

The choice of work and the adaptation to the configuration is of greatest importance.

If the slope presents an even surface, like a roof, the pile rows and walls are placed at intervals, so that the next series covers the even spaces of the one before.

In ravines, the work is to be placed where the slope changes to the steeper wall. Large bowlders or rocks rising above the surface are often the incipient cause of slides. The safety-work is to be placed at their foot, so, however, that the snow sliding from such elevations should not fall upon the wall, but in front of it, to be there retained.

Springs and collections of seepage water must be taken care of and properly conducted.

A yearly inspection and repairs are, of course, necessary.

After the starting-point of avalanches has been thus secured reforestation is at once begun, with such species as belong to the locality. The planting is done with seedlings, at a distance of 40 inches, as a rule. This reforestation of the tracks of avalanches, especially in steep situations, including after-planting, is very expensive, and amounts to $25 to $40 per acre in Switzerland.

In conclusion, it may be stated that the Swiss Government bears 40 per cent.—in extraordinary cases 50 per cent.—of the cost of building retaining-works. In reforestation in existing protective forests, 20 to 50 per cent., and in planting new forests, 30 to 70 per cent. of the cost is borne by the Government, the communities being liable for the balance.

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ERRATA.

Page 75, last line, for 686,827 read 686,781.
Page 128, line 25, for Poplar read Aspen.
Page 128, bottom, for Vine read Dwarf.
Page 129, third line, for Poplar read Aspen.
Page 131, third line from bottom, transpose "long" and " wide."
Page 132, ninth line from bottom, for 21,000 read 2,100.
Page 133, fifth line, for 84 read 74.
Page 136, tenth line from bottom, for 7,600 read 8,490.
Page 136, add at last line, There are 15 miles of mining and milling ditches.
Page 137, tenth line, strike out " union colony."
Page 146, fifteenth line, strike out "and Mal pais."

DEPARTMENT OF AGRICULTURE.
FORESTRY DIVISION.
BULLETIN NO. 3.

PRELIMINARY REPORT

ON

THE USE OF METAL TRACK ON RAILWAYS AS A SUBSTITUTE FOR WOODEN TIES.

BY

E. E. RUSSELL TRATMAN, C. E.

TO WHICH IS ADDED

A REPORT OF EXPERIMENTS IN WOOD SEASONING BY THE CHICAGO, BURLINGTON AND QUINCY RAILROAD COMPANY, AND OTHER NOTES.

COMPILED BY

B. E. FERNOW,
CHIEF OF FORESTRY DIVISION.

WASHINGTON:
GOVERNMENT PRINTING OFFICE.
1889.

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LETTER OF SUBMITTAL.

FORESTRY DIVISION, DEPARTMENT OF AGRICULTURE,
Washington, D. C., February 28, 1889.

SIR: I have the honor herewith to submit for publication as a special Bulletin a preliminary report by Mr. E. E. Russell Tratman, C. E., on the use of metal track for railways, which gives, in concise form, information in regard to the use of this substitute for timber ties in foreign countries.

This report forms a fit sequel to Bulletin No. 1, from this Division, on the "Relation of Railroads to Forestry," which has found so much favor with railroad managers and engineers.

Recognizing that the enormous drafts of the railroads on our timber resources and especially on the young growth—the hope of our future forestry—are among the most dangerous factors in the exhaustion of our timber supply, it is in the interest of forest preservation to keep railroad managers informed of the possibilities in the use of substitutes and the advantages to be derived therefrom.

Through the courtesy of Mr. George C. Smith, manager of the Chicago, Burlington and Quincy Railroad Company, I am enabled to add, as of interest to the same class of readers, an account of the highly valuable experiments on seasoning of timber, undertaken by the chemist of that company.

Notes of interest bearing on the same line of inquiries, such as have accumulated in the Division since the issue of Bulletin No. 1, have also been incorporated in the present issue.

Respectfully submitted.

B. E. FERNOW,
Chief of Forestry Division.

Hon. NORMAN J. COLMAN,
Secretary.

METAL TRACK FOR RAILWAYS.

(Preliminary Report on the Use of Metal Track on Railways in Foreign Countries.)

LETTER OF TRANSMITTAL.

BROOKLYN, N. Y., *February* 1, 1889.

SIR: In accordance with the arrangements made some time ago, I have been engaged for several months in collecting material to be used in the preparation of a report to the Department of Agriculture upon the use of metal track upon railways in foreign countries; and I beg to submit, herewith, a brief preliminary report, showing the scope of my investigations, and giving a general idea of the extent to which such track is in use. Attention has for some years past been directed by the Department to the destruction of the forests of this country; and as the consumption of timber for railway ties is very great (as shown in Bulletin 1, of the Forestry Division, on the "Relation of Railways to Forestry," and subsequently in a paper by me presented at the annual meeting of the American Forestry Congress, at Atlanta, Ga., in December, 1888), suggestions have from time to time been made that some form of metal track should be introduced, both to effect an economy in the consumption of our timber resources and to give a more efficient, durable, and economical track. The matter has, however, been given very little practical attention, and it has been generally taken for granted that the use of such metal track in several foreign countries (of which the home and foreign technical journals give occasional information) has been entirely experimental. This is an erroneous impression, the facts being that experiments begun many years ago have led to the adoption of various systems of metal track in different countries. A number of the systems tried have proved fairly efficient in service, if not economical; the systems which have combined efficiency and economy are few, but such a combination has been effected, and there is no reason why it cannot be adapted to and applied in American practice. The experiments are still in progress, and careful records are being kept of the results obtained, both with regard to economy and efficiency; but the questions of the advantages and the feasibility of metal track have passed beyond the experimental stage, and metal track for railways has been brought to a very practical issue.

My first proceeding, after the preparation of the report had been decided upon, was to draw up a list of leading questions respecting the subject of my investigations and to have the list printed. A copy of this list is appended hereto. Personal letters have been written to engineers, managers, manufacturers, etc., in all parts of the world, asking for information, and in each case a copy of these questions has been inclosed in order to show the character of the information desired. At the commencement of this comprehensive system of correspondence I was not very sanguine as to the results, but after about a year's experience I find that they have been eminently satisfactory and have far exceeded my expectations. There have been written about two hundred and fifty separate letters of application, and replies have been received to about one hundred and twenty; some in brief, but a large number in detail, accompanied by plans, etc. These answers required acknowledgment and sometimes a request for further information, and this has entailed a very large amount of personal correspondence; aggregating, in all, between three hundred and fifty and four hundred foreign letters. This work has been rather laborious, but the matter collected has been well worth the trouble, while the work has resulted in the getting together of a mass of information which has probably never before been gathered for purposes of compilation and comparison. The home and foreign technical journals have also been closely studied. The varied information thus obtained, with details of the various systems experimented with or adopted, it is intended to present in full in the main report; meanwhile, I am continuing the investigations.

As the particulars respecting the length of line laid with metal track have been obtained from many separate companies and officers in many countries, it is difficult to even approximate the total mileage; but the figures given in the succeeding pages will prove the great extent of such track in the aggregate.

In Europe it is the usual practice, in addition to the use of metal track for railways, to use steel or iron longitudinals or cross ties, or cast-iron "chairs," for street railway tracks, using no wood at all, but only metal and concrete. Steel ties are also extensively used for contractors' tracks, portable railways, narrow-gauge and light railways, etc., in various parts of the world.

With regard to this country, very little has been done, although from time to time a few ties of different patterns have been put down experimentally. The Pennsylvania Railroad has tried the steel tie used on the London and Northwestern Railway of England, but the trial included the entire system of English track,* with its objectionable double headed rail supported in chairs; a form of track which it is to be hoped will never be introduced in this country. This trial does not count for much, especially as the tie complete is very expensive, owing to the amount of shop-work. (See "England.")† The Boston and Maine Railroad has tried a few wrought-iron plate ties, and the New York Central and Hudson River Railroad has tried cast-iron "pots" experimentally on a small scale. This latter road will make a careful trial of the "Hartford" steel tie, which promises well; eight hundred of these ties have been ordered and will be laid in April. Another tie about to be given a practical trial is the "Standard" steel tie, in which the rails rest on wood blocks, on end grain, the arrangement being somewhat similar to a form of track tried on the Eastern Railway of France. Of these types of ties, however, I prefer to say nothing further at present, for the reason that however advantageous they may seem, practical service alone can decide as to their practical advantages; and, if successful, they will doubtless be modified to some extent to meet requirements met with in experience, as has been the case with the "Post" and all other successful forms of ties.

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* For description of this, see my paper on "English Railroad Track," in the Transactions of the American Society of Civil Engineers, June, 1888.

† Four or five different types of ties have been tried by the Pennsylvania Railroad Company, all of which have been taken out, with the exception of those obtained from the London and Northwestern Railway (England), which, as stated, have been

It should be borne in mind that metal ties should be adopted not only as a substitute for timber when the latter becomes scarce or expensive, but also (and more particularly on main lines) as giving a better and more efficient form of track for fast and heavy traffic. For a further explanation of this view I would refer to a paper on "Maintenance Expenses of Track on Metal and Wooden Ties," by J. W. Post (with a discussion written by myself), in the Transactions of the American Society of Civil Engineers, June, 1888.* Descriptions of some of the earlier forms of metal track are given in Engineering News, New York, January and February, 1887.

In concluding this introduction, I give the following abstract of the opinions presented at the International Railway Congress, held at Milan, Italy, in 1887: The opinion presented at the Congress at Brussels, in 1885, that metal ties are able in point of efficiency to compete with wooden ties, is not weakened by the results of experience of the two years, and the use of metal ties is extending. In point of economy, considering the first cost and the durability, the result depends upon the material, the state of the metal market, and upon local circumstances. As to the cost of maintenance, the question was not considered to be fully decided on lines with a fast and heavy traffic, but for lines with moderate traffic and speed it was the opinion of the majority that the metal tie presented advantages, especially after the lapse of a sufficient time for the earth works to have thoroughly settled and for the taking up of all slack in the fastenings.

I am, sir, respectfully yours,

E. E. RUSSELL TRATMAN,
Jun. Am. Soc. C. E.

B. E. FERNOW,
Chief of Forestry Division, Department of Agriculture.

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found objectionable. It is also stated that as long as white-oak ties can be got at 65 to 70 cents each it would be foolish to use metal ties, "costing $3 to $4" each. That the cost for metal ties is not necessarily as high as that given as objectionable will appear further on in this report; a good tie (Durand patent) being claimed to be produced from old rails at the cost of $1.—B. E. F.

* See reprint in this Bulletin, p. 25.

CIRCULAR.

The following circular was addressed to various railroad companies and managers in Europe and other countries.

Metal Track for Railroads.

The information outlined below is desired for the purpose of a report to the U. S. Department of Agriculture on the use of metal ties (sleepers) for railroad tracks, and it is requested as a favor that all information furnished should be as complete as possible and sent at the earliest possible convenience.

Respectfully,

E. E. RUSSELL TRATMAN, C. E.,
144 *Remsen street, Brooklyn, New York, U. S. America.*

INFORMATION.

Railroad:

1. Name.
2. Route.
3. Length of lines laid with metal sleepers.
4. Character of same. (Particulars of grades, curves, etc.)
5. Dates when laid.
6. Engineer in charge.
7. Character of traffic.
8. Weight of locomotives and weight on driving wheels.

Sleeper:

9. Longitudinal, transverse, or bowl.
10. General form.
11. Dimensions, including thickness. (Figured drawings.)
12. Weight.
13. Material.
14. Spacing center to center.
15. How treated. (Paint, anti-rust process, etc.)
16. Manufacturer.
17. First cost, at factory or delivered.
18. Expense of maintenance.
19. Attachment of rails. (Details and drawings.)
20. Arrangements for curves.

Sleeper—Continued.

21. Tie-rods; if used, how attached and adjusted for gauge.
22. Durability.

Track:

23. Material of ballast.
24. Behavior of ballast under sleeper.
25. Construction of road-bed. (Drawing.)
26. Section and weight of rail.
27. Rail joints; how made.
28. Rail joints; on sleeper or suspended.
29. Reasons for adopting metal sleepers.
30. General results: satisfactory or otherwise.
31. Is there trouble with maintenance of track?
32. Is there trouble with rail attachments?
33. Is there trouble from breakages; how and where do they usually occur?
34. Efficiency, etc., as compared with wooden sleepers.
35. Cost, material, and durability of wooden sleepers.
36. Climate; and effect of same on metal or wooden sleepers.
37. General remarks.
38. Opinions.

REPORT.

EUROPE.

England.—In England, steel ties have during the past few years been tried to a greater or less extent on quite a number of the principal lines. Foremost among them is the London and Northwestern Railway, which has between 20 and 30 miles of track laid with the steel cross-tie invented by Mr. F. W. Webb, the locomotive superintendent of the road. In 1888 there were 83,204 of them in use, and the experience with them had covered then six and one-half years. These ties have been experimented with on the Pennsylvania Railroad.

The general type used is the steel "inverted trough" in different forms, either rolled or stamped. As the system of track, however, includes the double-headed rail, these ties are fitted with the usual heavy cast-iron chairs to hold the rail (the Webb tie has the chairs made of steel plates), and the track is unnecessarily heavy and costly. The chief difficulty is said to be in adapting the steel tie to the double-headed rail, it being difficult to make a good piece of work. The North-eastern Railway, however, is trying steel ties under flange rails weighing 90 pounds per yard, which is a step toward the ideal track for main lines.

France.—Experiments with metal cross-ties have been made on nearly all the principal railways, and a large number of types have been tried, but several of them have been of complicated design, and therefore uneconomical. Longitudinal systems have been tried to a small extent.

On the State Railways a number of trials have been made, and with some forms of tie very good results have been obtained, enabling a reduction to be made in the maintenance staff. In 1886 there were ordered 17,000 ties of the "Post" type and 80,000 ties of the old "Berg-et-Marche" type. In 1888 there were (*a*) 2.10 miles laid with the "Paulet-Lavallette" ties, with double-headed rails in chairs; (*b*) 7.35 miles laid with a tie similar to the "Post" type, with double-headed rails, and 30,000 more of these ties had been ordered; (*c*) 8.86 miles laid with similar ties, but with flange rails. Of these (*a*) had been laid in 1885, (*b*) and (*c*) in 1887. On the Paris and Bordeaux line, 4.4 miles of "Vautherin" ties of uniform thickness were laid between November, 1886, and February, 1887; 4.5 miles of "Vautherin" ties of varying thickness (similar to the "Post" type) were laid in February and March, 1887, and .56 mile was laid with the "Boyenval and Ponsard" ties in April, 1888.

The Paris, Lyons and Mediterranean Railway used an old type of iron tie several years ago, but abandoned it on account of the ties costing more than the wooden ties and giving a less firm and durable track;

this latter defect was probably due to the old-fashioned "gib and cotter" fastening employed. These ties were laid in 1862 and following years, and had all been taken out in 1872. Good results have been obtained with metal ties on the Algerian system controlled by this company. (See "Africa.")

The Northern Railway laid trial sections of its Belgian lines with the "Severac" and "Bernard" ties in 1885, and laid 10,000 of the former on its French lines in 1888.

The Western Railway, which used the old double-headed rail, has experimented with iron ties upon which the rail chairs were cast; about 1.3 miles were laid in 1887.

The Eastern Railway has tried steel ties with wooden cushions or bearing blocks under the rails, and has also laid about one hundred of the "Post" ties.

Holland.—In this country probably the most extensive and most valuable, because continuous and systematic, trials have been made, and the trials have resulted in improvements which have served to develop the now well-known and extensively-used "Post" steel cross-tie of varying thickness, the thickness being increased under the rail seat. The "Post" tie, the invention of Mr. Post, the engineer of permanent way of the Netherlands State Railway Company, is economical both in construction (owing to its requiring a minimum of shop-work, all of which adds to the cost of a tie) and in maintenance, and has proved very efficient in service.

On the Netherlands State Railways the experiments have been in progress since 1865, and the steel tie designed by Mr. Post and improved by him from time to time in the light of practical experience has been adopted on this system. In the early part of 1888 the system, which comprises 910 miles of road, had 91 miles of track laid with these ties. Of 10,000 ties laid in 1865, 9,550 were still in the track and were expected to last twenty years more, although they were of the earlier type of the tie, which has since been improved upon. As to breakages, out of 162,634 ties laid, not one had broken.

In the early part of 1888 there were in use 457,300 ties (about 23,800 tons) of the "Post" type in Holland, Belgium, France, Germany, Switzerland, and Asia (colonies); about 272,700 ties (about 12,700 tons) more, including ties for narrow-gauge railways and for the rack railway in Sumatra, were being manufactured; making a total of about 730,000 ties, or 36,500 tons, of this one type. (See page 25.)

Belgium.—On the Belgian State Railway system the "Post" tie has been laid, but it is heavier than that used on the Netherlands State Railway and heavier than the inventor considers necessary or desirable. It should be noted that it is not economical to use more metal than experience has shown to be necessary. Experiments have been made on rather a large scale, and in 1887 three types were experimented with on various lines, and one of these types appeared to meet the requirements for fast and heavy traffic. In 1885 it was decided to put down

35,000 ties of the "Post" (old) type, 35,000 ties of a type invented by the chief engineer of the road, and 5,000 ties of the "Bernard" type. Some "Bernard" ties were also laid in 1886–'87.

The Grand Central Railway has also had satisfactory results with metal ties. In 1873 the superintendent of permanent way reported that he was fully satisfied with the experience then acquired with metal ties, but he was unable to adopt them further at that time owing to a great advance in the price of iron. In his reports for 1886 and 1887 he stated that the favorable results had been still more marked, and during 1887 there were 6,000 metal ties laid.

Metal ties of the "Coblyn" type, for light railways, have been definitely adopted by the Société Anonyme des Chemins de Fer Économiques, and have also been tried on the lines of the Société Nationale des Chemins de Fer Vicinaux, the Netherlands lines, the Liegeois and Luxembourg division (on Belgian territory) of the Netherlands State Railway, and on the Liege and Seraing line. Metal ties have been tried on the Belgian division of the Northern Railway of France, including 5,500 ties of the "Bernard" type.

Germany.—On the State Railways a number of different systems of metal track of longitudinal and transverse types have been tried for several years, and some types have been regularly adopted on certain divisions. The investigations and trials are still in progress. In 1887 the State Railway system had a length of about 13,193 miles, with about 23,662 miles of track; of this amount about 5,530 miles had metal track—3,131 miles being laid with cross-ties and 2,399 miles with longitudinals. Very careful records of the trials have been kept. In the year 1886–'87 there were laid 868,262 new cross-ties and 64,094 longitudinals. In February, 1888, 500,000 "Post" ties were being made for German lines.

For the Rhenish Railway system 308,000 ties (10,775 tons) were purchased in 1877–'79. On the Left-Bank-of-the-Rhine Railway, which comprises 1,681 miles, there are 943 miles with metal cross-ties and 211 miles with longitudinals, the balance being on wooden cross ties. The first cross-ties were laid in 1876 and the first longitudinals in 1872. Since 1879 metal sleepers only have been used. On the Elberfeld division of the Prussian State Railways (1,646 miles) there are 790.5 miles laid with wooden ties, 762.5 with iron ties, and 93 miles with iron longitudinals. They were laid in different years between 1869 and 1880.

The experience with iron longitudinals and cross-ties was very favorable, but still better results have been obtained since steel was introduced. Wooden ties are still used in great numbers, partly on account of their lower first cost and partly on account of the policy of the Prussian Government to keep up the supply of timber by domestic cultivation and forest management.

Austria.—In this country, longitudinal systems of metal track have been extensively used. The Northwestern Railway has a total of 59½ miles of track laid with the "Hohenegger" system of longitudinals, and the economy over wood is reported to be noticeable. These longitudinals have been laid in small sections year by year since 1876; the earlier ones were of iron, but the latter ones are of steel. The "Heindl" system of longitudinals is in use on a number of roads; the first were laid in 1883, and at the end of 1887 there was an aggregate of about 141 miles laid with this system of track, a considerable portion being on mountain divisions and including 6.634 miles on the Arlberg tunnel line.

Switzerland.—The Central Railway had 100,000 metal ties in use at the end of 1884, and proposed to lay 30,000 per annum till its whole system had been thus laid. The Western and Simplon Railways began using metal ties in 1883, and have been very well satisfied with them. The Gotthard Railway uses them very extensively, and they have also been adopted on the Mount Pilatus Rack-Railway. In February, 1888, the Hoerde Works reported that they were delivering 160,000 "Post" ties to the Gotthard Railway and 160,000 to the Western Railway.

Italy.—Metal track has been used very little, if at all, and oak ties are obtainable in ample quantities and at a moderate price; and as there are extensive timber resources such track will not be necessary for many years. It has been proposed, however, to lay steel ties on some sections of the Mediterranean Railway system. The Government has used steel ties for short military railways in its African campaigns.

Spain.—The line from Bilbao to Las Arenas has 7.1 miles laid with steel cross-ties, and it is believed that they will prove more economical than wood. The line is 1-metre gauge. The Almanza, Valencia and Tarragona line has 251 miles laid with the De Bergue system of cast-iron plates connected by tie-rods. This system is found to give greater economy, and the gauge is maintained better than with wooden sleepers. The division between Valencia and Tarragona was laid with this track in 1860, and the division between Almanza and Valencia in 1873.

Sweden.—On the State Railways about two-thirds of a mile were laid with metal ties, for experimental purposes, in June, 1886. This is the only case where they have been used in Sweden or Norway.

Denmark.—On the State Railways steel cross-ties were laid for about 18 miles in 1883–'84; but the results, as reported to me in 1888, have not been entirely satisfactory, owing to the insufficient weight and strength of the ties.

*Russia.**—Metal ties have only been used to a very limited extent, on two branch lines, and even there they have not been sufficiently used to enable any reliable conclusions to be drawn from the experiments.

AFRICA.

Cape Colony.—The Cape Government Railways have some sections of the lines laid with cast-iron bowls; they are arranged in pairs and connected by transverse tie-rods. The Delagoa Bay Railway, one of the new lines opening up the interior, is laid principally with steel ties.

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* The metal ties laid on the Moscow Kursk Railway were removed because their maintenance was found more expensive than that of wooden ties. It is claimed that at present prices for wood and for metal in Russia, the metal ties, weighing 105.8 pounds, with an estimated duration of thirty-five years, were two and a half times as expensive as the pine ties impregnated with chloride of zinc, lasting ten years, and one and one-half as expensive as oak impregnated and lasting six years. Conditions in Russia, however, are exceptional as regards labor and material.—B. E. F.

Senegal.—About 5,000 ties of the "Severac" type have been ordered for the railways in this French colony. Cast-iron bowls are used on the French island of Réunion.

Egypt.—On the Egyptian Agricultural Railways, wrought-iron plates connected by tie rods have been used, and also cast-iron "pots" or bowls. In the English campaign of 1885 a short length of light railway of 18-inch gauge, with corrugated steel cross-ties, was laid at Suakim, but the line was soon taken up.

Algeria.—Metal ties are used on the Algerian lines controlled by the Paris, Lyons and Mediterranean Railway Company (France); 10,000 ties were laid in 1870, and have given good results. In 1867–'69 the Algiers and Oran line put down 90,000 iron ties of the "Vautherin" type; the Bône and Guelma line put down 3,500 ties of the "Severac" type and 2,500 of the "Boyenval-Ponsard" type. It is estimated that the use of metal ties has saved one-fourth of the labor formerly required for maintenance, or about $60 per mile per annum.

ASIA.

India.—In this country, steel cross-ties and cast-iron bowls and plates (the latter types arranged in pairs) are very extensively used, and the use of metal track is extending very rapidly, large contracts being frequently awarded for the companies' and the Government lines. Even in Burmah, where wood has been generally used till recently, steel ties are beginning to be introduced.

About 525,000 tons of steel ties have been sent out from England during the last few years, and there are nearly 300 miles of the State lines now laid with this form of track; a large number of miles of private companies' lines are also laid with steel ties. The general results are reported to be good, and the ties give, on the whole, much satisfaction. They are used for lines of 1 metre and 5 feet 6 inches gauge.

There are over 1,600 miles laid with cast-iron track of different types, and these also give satisfactory results in general. Such tracks have been in use for twelve or fourteen years. Of the "Denham-Olpherts" type alone more than 2,000,000 pairs have been made for double-headed rails and about 600,000 pairs for flange rails. On the East Indian Railway there were 1,311,000 of these "Denham-Olpherts" plate sleepers at the end of 1887, and the breakages since 1885 had averaged only 0.84 per cent. per annum. They give good results in reducing the work of maintenance, there being a saving of about 6½ per cent. of renewals per annum. In some of these sleepers wooden cushions are used for the rails to rest on. On one division of the Indian Midland Railway the percentage of renewals of the "Denham-Olpherts" plate sleepers was 0.31.

Japan.—A few cast-iron "pot" sleepers were laid when the first lines were built, about 1871, but they have nearly all been taken up again and hardly any now remain in the track, while for new lines timber ties are used exclusively.

China.—Steel cross-ties are to be tried as an experiment on the new railway which was opened last year.

AUSTRALIA.

Queensland.—The first metal sleepers ever made in Australia have been tried in this colony, an experimental section of a few miles long having been laid with the "Phillips" type. This is a steel cross-tie intended for prairie work, where the track is laid on the surface of the ground; it is designed to be used without ballast, being simply packed with surface soil. Some years ago about 1,000 wrought-iron ties were laid, but they only lasted about five years, as they generally fractured under the rail-seats, owing, it is said, to defective fastenings; they were laid in broken-stone ballast.

In regard to the "Phillips" type, Mr. Phillips kindly reports to me as follows, under date of January 2, 1889, and it is especially interesting as showing that metal track is adapted for other lines than those with heavy traffic:

> I have just returned from North Queensland, where I have been constructing a section of railway 36 miles in length on my system. The country I am dealing with is between the port of Normanton, in 17° 45′ S. lat. and 141° 10′ E. long., and a new goldfield by the name of Croydon, situated about 85 miles E. S. E. from Normanton. The country is almost uniformly even, and the Norman River is the only important river crossed. The first 4 miles are over gravel ridges, when a descent of 1 in 70 for half a mile brings the line down to the level of the river flats; the soil is dark clay with a slight admixture of alluvial sand. This description of country extends to 14 miles, where the river is crossed with a low level timber bridge (principally 20-feet spans) on a sandstone rock bottom. Thence to Croydon the country is very uniform in character—fine sandy soil, covered with a more or less thick forest of inferior and stunted timber, sometimes dense enough to be called brush or scrub. There is no forest timber of sufficient dimensions in the district available for ties or bridge work, neither is there any stone for ballast, except by quarrying below the surface, and that is sandstone of an inferior and very soft description. The country is almost uniformly even, except at the 4-mile peg, where there is a cutting of about 5 feet and an embankment of equal height. I commenced track-laying July 7, and completed 32 miles on December 29; fully seven weeks were lost through non-delivery of ties, so that the average rate of progress was 1¾ miles per week of six working days. The number of men employed in (*a*) clearing track 66 feet wide, (*b*) grubbing, (*c*) ploughing, harrowing, and rolling central width of 10 feet, (*d*) track-laying, (*e*) lifting and packing ties, and (*f*) straightening track, never exceeded 65, with one team of bullocks (12) and one horse. Cost per mile for labor only, $630; wages for laborers, $2.50 per day; gangers, $3.15. The ploughing, harrowing, and rolling cost $75 per mile, and is included in the $630. The total cost was under $15 per lineal foot. The best day's work was .525 mile, and the best week's work a little over 2 miles. No ballast has been provided and no side or cross drains cut; the only waterways are at well-defined and water-worn channels. The total timber bridging on the 36 miles is 1,108 lineal feet, and only one box-drain has been put in. From 20¼ miles to 36 miles there is not a single water-way of any description. The cost is under $15 per lineal foot.
>
> The material train has never failed to run to the head of the road daily, from the commencement of track-laying, although there have been some very heavy thunderstorms with 1 to 2 inches of rain-fall in an hour. The track is laid with steel flange rails, 41¼ pounds per yard, 26 feet long, fastened to mild steel cross-ties, weighing 84 pounds each, 11 ties to a rail length. The average gross load of the material train,

100 tons. The locomotive employed is a six-wheeled engine of English build. The country passed through is believed to be the softest in wet weather to be found in Australia, but so far no trouble has been experienced with the line. The country is infested with white ants (termites), and ties of the best hard woods of the colony will not last more than 3 years in the form of ties. The government now in power are not very favorable to my system, but I hope to be able to induce them to complete the Croydon Railway on my system. I believe my system might be applied with advantage to your prairie country subject to heavy rain-falls.

New South Wales.—About 1,000 steel cross-ties were laid in 1882. In 1887 it was reported that they were in bad condition, but this may have been due (if correct) to the fact that the manufacture of steel ties was in its infancy in 1882.

South Australia.—In March, 1888, the agent-general in England reported to me that metal sleepers were being laid on a new line 145 miles long, not then open to traffic.

SOUTH AMERICA.

Argentine Republic.—In this State, cast-iron "pot" sleepers are used almost exclusively, except in the far west and north. The Buenos Ayres Great Southern Railway, which began operations in 1865, has 13¾ miles of double track and 819½ miles of single track laid with cast-iron sleepers of an improved design. They are adopted on account of the difficulty of procuring good hard-wood ties in sufficient quantity and the greater expense of these wooden ties; also because they give a more rigid and satisfactory track. The Central Argentine Railway has 246 miles laid with cast-iron track. The Santa Fé and Cordoba Railway ordered 20,000 steel ties in England in 1888.

Chili.—Steel ties have been tried to a small extent, but the type was considered too heavy and expensive. Previous to the award in November last, to an American syndicate, of the contract for building about 780 miles of railways for the State, proposals had been invited by the Chilian legation in France for the supply of 739,400 metal ties 9 feet long and 725,100 ties 4½ feet long.

United States of Colombia.—There has been some talk of adopting metal ties on the Bolivar Railway.

MEXICO.

The Mexican Railway (Vera Cruz line) is using a large number of steel ties of the type in general use in India, and has obtained very good results with them, especially at times when the road has been flooded. These ties were first used in 1884, and at the end of June, 1888, there were 46½ miles of track laid with steel ties. The Mexican Central Railway has been contemplating the adoption of the same type of tie on the mountain division of the road, the advantages being that they last longer than wooden ties and keep the track in perfect gauge.

The above report is respectfully submitted for consideration.

E. E. RUSSELL TRATMAN,
Jun. Am. Soc. C. E.

FEBRUARY 1, 1889.

Appendix A.

THE "POST" TIE.

This tie, of which so much has been heard, is probably the most successful of all the various types of metal ties that have been put in service, and the success is largely due to the care which has been taken in noting the results obtained and in making such improvements as experience has shown to be desirable. Consequently, the present form of the tie is the result of many improvements, and represents several years of experience and careful study. It is a cross-tie rolled from mild steel (Bessemer, Thomas, or Siemens-Martin); its section is that of an inverted trough, with flaring sides forming a section of a polygon; it is narrow and deep in the middle, the ends are closed, and the bottom edges are thickened to form a rib. One of its special features is its varying thickness, giving an ample thickness of metal at the rail seat, where the greatest strength is required, and a less thickness at the middle and ds. Thus the weight of the ties as now used is from 110 pounds to pounds each, corresponding to 126.5 and 139.15 pounds if they were uniform section. This feature represents, therefore, an economy of 15 per cent. of metal as compared with a tie with a uniform thickness equal to the maximum thickness of the "Post" tie. In the operation of rolling, the varying thickness is given and also the shape of the tie, while the bending of the ends to give the rails an inward inclination of 1 in 20 (in accordance with European practice) is done during the same operation.

The shape of the middle portion of the tie is designed with a purpose, as it is claimed that by narrowing this portion the ballast is kept from working away from under the rail seat, and in this way a stable road-bed and track are secured, thus diminishing the work of maintenance. It prevents the tendency of the ballast to work towards the middle and form a ridge on which the tie would rest, giving a rocking motion to the track, but gives it a tendency to pack well under the rail seat. The increased depth of this portion gives additional strength to resist bending and also offers increased resistance to creeping.

The following are the principal dimensions, given in the original metric measure and also reduced to feet and inches: Length over all, 2.55 to 2.65 metres (8.364 to 8.692 feet); width over all at rail seat, 235 millimetres (9.40 inches); width over all at middle, about 5.30 inches; width of rail seat, 110 millimetres (4.40 inches); width of end, 280 millimetres (11.20 inches); depth under rail, 74.5 to 75.5 millimetres (2.98 to 3.02 inches); depth at middle, 125 millimetres (5 inches). Thickness of cross-section at rail seat varies as follows: Thickness at bottom of flange, 6 millimetres (.24 inch); thickness at upper part of flange, 7 millimetres (.28 inch); thickness at rail seat, 9 to 10 millimetres (.36 to .40 inch); thickness at bolt-holes, 12 to 13 millimetres (.48 to .52 inch); thickness at middle and ends, 6 to 7 millimetres (.24 to .28 inch). The rib on the lower edge of the flanges has a depth of about 18 millimetres (.72 inch). and projects about 13 millimetres (.52 inch) beyond the outer face of the flange.

For narrow-gauge and light railways the dimensions would be reduced in accordance with the weight, and for such lines a weight of 72.6 to 77 pounds is considered sufficient.

For rail fastenings reliance has been placed upon bolts, and the results have been entirely satisfactory; the fastenings keep tight, prevent vibration and rattling, and require little attention after the track has become well settled. The bolt-holes are oblong, and have rounded corners. The bolt used is 91 millimetres (3.64 inches) long and 22 millimeters (.88 inch) in diameter; it has a T-head 38 by 46 millimetres (1.52 by 1.84 inches), and a cam-shaped or eccentric neck 22 by 30 millimetres (.88 by 1.20 inches), for the purpose of allowing an adjustment of gauge at curves, switches, etc. The bolt passes up through the tie and through a "crab" washer which bears on the flange of the rail and the face of the tie; a Verona nut-lock is then put on and the nut screwed down upon it. The upper face of the washer and the lower face of the nut are indented, so as to give a good hold on the nut lock. The ties are sent out to the track with the fastenings separate in kegs, or with the bolts in place and the nuts loosely screwed on, according to the wishes of the division engineers; some of whom prefer one plan and some the other.

This tie presents the following advantages:

First. Economy in material; owing to the maximum thickness being given at the rail seat and a less thickness at the middle and ends, this effects a decided saving in weight and first cost.

Second. Economy in manufacture; owing to the shaping, bending, and varying of the section being all done in the operation of rolling, thus reducing the shop-work to a minimum; which is an important consideration.

Third. Economy in maintenance; owing to the little care and attention required, as shown by years of actual service.

Fourth. Efficiency in making a good track; as also proved by years of actual service.

Fifth. Adjustment; owing to the arrangement of the fastenings permitting the gauge to be widened at curves and narrowed at switches; which is an important feature when a tie is adopted on a considerable length of track.

E. E. R. T.

Appendix B.

SOME AMERICAN METAL TIES.

The International tie.—This is a rolled steel tie, the section of which resembles a printer's "brace" (⏞); originally it was made in two pieces, riveted together at the middle flange, but it is now to be rolled in one piece. The dimensions are as follows: Length, 8 feet; width, 10 inches; side flanges, 2¾ inches deep; middle flange, 2 inches high; thickness, from $\frac{3}{16}$-inch at the lower part of the side flanges to $\frac{5}{16}$ inch at the middle. The middle flange is cut away in two places for the rails. The fastenings consist of flat wrought-iron clips, one on each side of the rail, which are bolted to the flange of the tie and have projections which bear upon the rail flange. Some of these ties have been in use for more than two years on the Boston and Maine Railroad and the Maine Central Railroad; the Long Island Railroad is now giving them a trial.

The Hartford tie.—This is a rolled steel tie, of inverted trough section, with a channel or groove along the whole length of the top table, and having the ends curved down to hold the ballast. The dimensions are as follows: Length, 7 feet 6 inches; width at top, 8 inches; width at bottom, 10¼ inches; depth, 2½ inches; thickness, ⅜ inch at sides and $\frac{5}{16}$ inch at top; the channel or groove is 2½ inches wide and ⅝ inch deep. The weight is about 120 pounds. The fastening for each rail consists of two clamps ⅝-inch thick, with a hooked projection at the broad end, which holds the flange of the rail; these clamps are wedge-shaped in plan, and lie in the channel above mentioned. A bent bolt, with its head at an angle of 53 degrees with the body, is used on each side of the rail; the head is on the under side of the tie and the body passes up through the tie and clamp, the nut bearing on the inclined face of the clamp. This is the fastening as improved by Mr. Katté, the chief engineer of the New York Central and Hudson River Railroad. By this arrangement, the bolt being at an angle, a strong grip is secured, and there is little tendency to jar the bolts loose; to prevent such loosening, however, the bolt has the Harvey grip thread, which forms a nut-lock in itself. The fastening permits of a very wide range of adjustment of gauge. These ties have not yet been tried, but the New York Central and Hudson River Railroad will lay 800 of them in April, and careful observations will be made as to the results.

The Standard tie.—This is a steel tie of channel section (⊔) stamped to shape from a plate. The bottom is cut away at the middle, and is bent up at an angle to offer resistance to lateral motion, the ends being open. The rail does not rest upon the vertical sides of the tie, which are cut away for a depth of three-fourths of an inch under the rail, but rests upon a block of preserved wood (placed with the grain vertical). The tie is intended to be filled with ballast. The fastenings consist of **Z**-shaped clips, the upper part holding the rail-flange and the lower part taking a bearing on the under side of the bottom of the tie; the upright web is nearly vertical, but curved so as to grip the wood block. A bolt passes horizontally through the two clips and the block, near the top of the latter, holding all the parts firmly together. At the rail-joints it is intended to use a tie of extra width, with wide clips and two bolts, and it is claimed that this fastening will be sufficient in itself, and will obviate the necessity of using splice plates. These ties have not yet been in service, but arrangements have been made for their manufacture, and it is said that they will soon be tried on a Western road. The claim is made that they are specially adapted for roads with a narrow width of ballast, owing to the resistance to lateral movement being at the middle instead of the ends of the tie.

The Taylor tie.—This is an iron or steel tie on the "bowl" system, each tie consisting of a separate piece under each rail, connected by a third piece forming a tie-bar. The rail-bearers are short pieces of inverted trough section, placed longitudinally with the rail, and have a vertical transverse slot through which the deep flat tie-bar passes. The inside flange of the rail is held by clips, forming a part of the top table of the trough, and the outside flange is held by a hooked projection at the end of the tie-bar. No bolts or other loose parts are used.

The Toucey tie.—This is a cast-iron "pot" tie designed by Mr. Toucey, general superintendent of the New York Central and Hudson River Railroad. Each tie consists of two "pots," of **H**-section, with outward flaring sides; the "pots" are connected by a tie-rod, the ends of which are bent at right angles to fit into a hole in the horizontal web, the rod passing through a hole in the side. The "pots" are 18 inches long, $9\frac{3}{4}$ inches wide on top, $16\frac{1}{2}$ inches wide at bottom, and $8\frac{5}{16}$ inches deep; the thickness varies from one-half inch to 1 inch. The space above the web is filled with an oak block, to which the rail is secured by the Bush interlocking bolts. These ties are in use at the Grand Central Depot in New York City.

A channel tie.—A channel tie was used by the Pennsylvania Railroad for some years subsequent to 1880. In that year some were laid on the Filbert Street extension, and in 1885 about 400 or 500 were laid on the main track in the West Philadelphia yard. The tie consisted of an ordinary 7-inch channel iron (⊓) 8 feet 6 inches long; the ends were closed by a piece of angle-iron riveted on, and a cross piece of angle-iron was also riveted inside the channel, just under the outer flange of the rail. The fastenings for each rail consisted of a piece of angle-bar riveted to the face of the tie (the rivets passing through the angle-bar, tie, and inside angle-iron) on the outside of the rail, and a loose flat clip on the inside of the rail, fastened by bolts. Writing in 1886, Mr. Brown, the chief engineer of the Pennsylvania Railroad, said:

> These ties cost from $3 to $4 each. As long as we can get good oak ties for not exceeding $1 each, I would not recommend making the change, although they give perfect satisfaction and are no more trouble to keep in line and surface than wooden ties.
>
> E. E. R. T.

THE DURAND TIE.

This tie, among the latest patented in this country, has been in use on a private trial line in the French Alps.

It resembles most nearly the "Post" tie.

It is produced by converting old rails into metal sheets, from which the tie is stamped out by special machinery, requiring no further shop work than the fastening of the bolts, which are welded to the tie while hot.

The cross section is of the "Vautherin" or "Zores" type, like the "Post" tie, narrowed, and depressed in the center and slightly curving towards the ends, as well as to the middle of the tie. Lengthwise corrugations on the face of the tie under the rail-seat, and if deemed necessary, vertical corrugations on the side-faces, are intended to give additional strength, allowing a saving of metal as against the "Post" tie. The width on top under the rail-foot is 10 inches and across the lower edges 12 inches.

The ends are open but can be closed if desired by a special cap, which is put on after the tie is placed and can be easily removed if necessary, permitting access to the lower side, bolts, etc., without removing the tie entirely. Experience, however, with the open-end type seems to have proved that the curvature of the ends is sufficient to prevent the blowing out of ballast.

The fastening of the rails is effected by means of four bolts with specially-fitted T-heads, which are inserted and partially welded to the tie from below during its manufacture, and are prevented from turning by a shoulder in the tie. A washer of soft metal is so adapted as to prevent any loosening of nuts above, an indentation on the lower side fitting into a similar indentation in the tie, and one flange being bent upwards after screwing down.

For curves, switches, etc., the adaptation of shape, inclination, and gauge is effected in the manufacture by interchangeable pieces in the stamping apparatus.

The placing of the tie is effected by laying it on the ballast and burying it in the same by means of a rocking motion with the help of levers inserted into holes made at the ends of the tie in manufacturing. No digging of a tie-bed, no tamping is needed. The drainage, a very important requirement, is well provided for.

The weight of the tie is made variable by either rolling the metal-sheets to three-sixteenths of an inch, which gives a 65 pound tie, or five-sixteenths of an inch, which will make it about 100 pounds.

The cost is claimed to be $1 or $1.35 respectively, if manufactured in the United States. The cost of manufacture is calculated at 30 cents, allowing a railroad company to use up the old rails. The plant for rolling the rails to shape and stamping the tie is simple; its cost is estimated at $5,000.

The Durand tie, with less metal, promises to give the same strength and is more easily placed than the "Post" tie.—B. E. F.

METAL TIE NOTES.

The following matter has been appended as of interest in the discussion of the desirable change from wooden to metal ties.

These notes originate in part with Mr. Tratman, or else are copied from other publications.

The ephemeral literature on the subject is growing rapidly, and by the time Mr. Tratman's final report will go to press, it will have become desirable, with it, to present in abstract the useful information which has thus accumulated. By that time it is hoped that more experiences from trial tests on railroad lines of our own country may also be recorded.

As this Bulletin goes to press, two interesting items of news on the railroad tie question have reached this office. The one relates to the remarkable durability of lignum-vitæ cross-ties on the Panama Railroad—thirty-five years. That there is any likelihood, as some papers seem to anticipate, that this discovery will in any way influence the use of metal ties by possible competition of this wooden tie, I am inclined, for various reasons, to doubt.

Perhaps of more influence on this subject may become the introduction of stone sleepers in combination with the "Elastic Tie-Plate," which was originally intended to improve the track on wooden ties, but has proved itself of service on rock sleepers in an experiment made by the Ystad-Eslof Railway in Sweden. Yet we are inclined to think that even this kind of substructure, if found as efficient as is claimed, would not threaten as much competition with the metal track as it might at first appear to do, except under special conditions.

The theoretical requisites for a perfect metal tie are now quite well understood and have been discussed at length in Bulletin I, from this Division. The task of inventors henceforth must be, while complying with these theoretical requisites, to do it in such a manner as to reduce the cost of the manufacture to its lowest possible figure without loss of required strength. With the extendeg experience before us there can not longer be a doubt that it is possible to construct a metal tie which will be superior in all respects to wooden ties; yet to bring its first cost down to such a figure that the future saving in its maintenance need not enter into consideration, but may be taken as an agreeable surprise in the cost of management—this is what railroad companies are most bent on obtaining. Especially in our country, where the present accounting outweighs in importance all future possible profits, this consideration alone, of reduced first cost, may be sufficient to work a revolution in the use of railroad ties. On the other hand, the bugbear of cheapness, which is often mistaken for an equivalent of economy, is apt to mislead the inventor into risking the factors of safety and strength in order to attain cheapness.

"If a man wants a 'cheap' track he had better continue to pay 50 and 75 cents for wooden ties. And if he wants an economical track he must use steel ties with enough metal in them to insure permanency."

There is also no doubt that the metal tie which is suitable for one set of conditions is not suitable for others. The amount of traffic, and especially the condition of track and ballast, will dictate changes in shape, weight, etc.

It had been the intention to review all the patents which had concerned themselves with introducing metal for railway tracks, but the large number—not less than 256 patents so far, very many of which are obviously impracticable—made the task too laborious for the practical result to be expected from it. Therefore, only a brief reference list to these patents has been prepared by Mr. Tratman.

The first suggestion for the use of metal track seems to date back to the year 1839; a patent by J. Stimpson, proposing a construction of metal and wood combined, similar to a construction now much used in street railways. The next attempts did not follow until 1857, 1858, and 1861.

The flood of patents begins with the year 1883, the last five years having produced not less than one hundred and sixty devices.

Some of the more prominent devices, which have been actually manufactured in the United States, are briefly described in Appendix B.

B. E. Fernow.

MAINTENANCE–EXPENSES OF TRACK ON WOODEN AND METAL TIES.

By J. W. Post, permanent way engineer, Netherlands State Railroad Company.

Read at the annual convention of the American Society of Civil Engineers, July 2, 1888.

Though the track of European railroads shows in material, construction, and maintenance a great difference from the track on American lines, the following data concerning the use of steel cross-ties, gathered methodically since 1865 on the lines worked in Holland, Belgium, and Germany by the Netherlands State Railroad Company, may be of some interest to American railroad engineers.

The first trial of metal ties on the Netherlands State Railroad dates from 1865, in which year 10,000 Cosijns ties* were laid. In 1880 these ties, of a system now considered poor, had given satisfactory results as to the metal part during their fifteen years of service, but the oak blocks had to be frequently renewed. Moreover, the following considerations induced the company to search for a good metal tie:

First. It was feared that prices of timber would gradually rise, owing to the increasing devastation of forests.

Second. Even with the wood deemed best for ties, viz. oak, it was difficult to secure satisfactory results; some lots of oak ties, severely inspected, appeared first-rate when new, but had to be renewed after only one year of service. The time of felling seems to be of great importance, and cannot be determined at the moment of purchase even by the severest inspection.

Third. Even the best methods of impregnating proved unreliable; of ties coming from the same boiler some were quite saturated, others only on the surface; some lasted one year only, others twenty years. Uniformity in this respect is desirable for the track.

Fourth. No timber merchant guarantees his ties; whereas steel ties are generally guaranteed for two years.

Fifth. There is a great loss of interest during the time timber ties are piled in order to dry; whereas metal ties are often in the track before being paid for.

Sixth. There is a great loss of timber ties by bursting, caused by sunshine, water, frost, driving the spikes, etc.

Seventh. Timber ties being heavier than metal ties, the transport to the place where they are put in the track is more expensive.

Eighth. The difficulty and cost of the respiking and readzing of timber ties, and of the replacing by new ones, increases with the daily number of trains. Ties of more durable material are desirable also from that point of view.

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* This tie consisted of an I beam laid horizontally, thus ⊢⊣, with a wooden block under each rail.

Ninth. The selling price of old metal ties is considerably higher than the price of old timber ties.

Tenth. A calculation* of the total annual sum required for purchase, laying, maintaining, and renewing tracks on timber and on metal ties gave a favorable result for the metal.†

All these considerations induced the company to charge the writer in 1880 to study, both at home and abroad, the different systems of metal ties then in use, both from the point of view of manufacture and of maintenance, and to propose a method of trial enabling the company to get the most complete information possible on the subject.

This charge resulted in the following different systems of ties and fastenings being laid in the track from 1880 to 1888:

	Pounds.
Type I, Vautherin section; iron	88
Type II, Vautherin section; iron	103.81
Type III, Haarmann section; mild steel	110
Type IV, Haarmann section; mild steel	114.4
Type V, Haarmann-Lichthammer section; mild steel	95.48

	Ties.
In 1881, type I	4,133
In 1882, type II	4,001
In 1883, type III	2,089
In 1883, type IV	2,000
In 1884, type V	11,680

And from 1885 to 1888, about 126,000 ties, types VI, VII, VIII and IX, making about 150,000 ties of ten different types (including Cosijns). Of each ot the types, trial lengths, under different circumstances of grades and curves, were put under special observation, every hour of maintenance work and every renewed piece being scrupulously noted. As a base of comparison 1,120 first-rate new oak ties were laid in the track, the rails being fastened with the ordinary spikes The plate shows the different types of ties used.

At the same time different systems of fastenings were tried on the metal ties.

By trying the best improvements in shape, material, and manufacture, and by eliminating every year the faults of the preceding types, Mr. Post gradually arrived at types of ties and fastenings which, having shown great advantage in every respect over the preceding types, have now been adopted as standards for this railroad.‡ (Types VIII and IX.)

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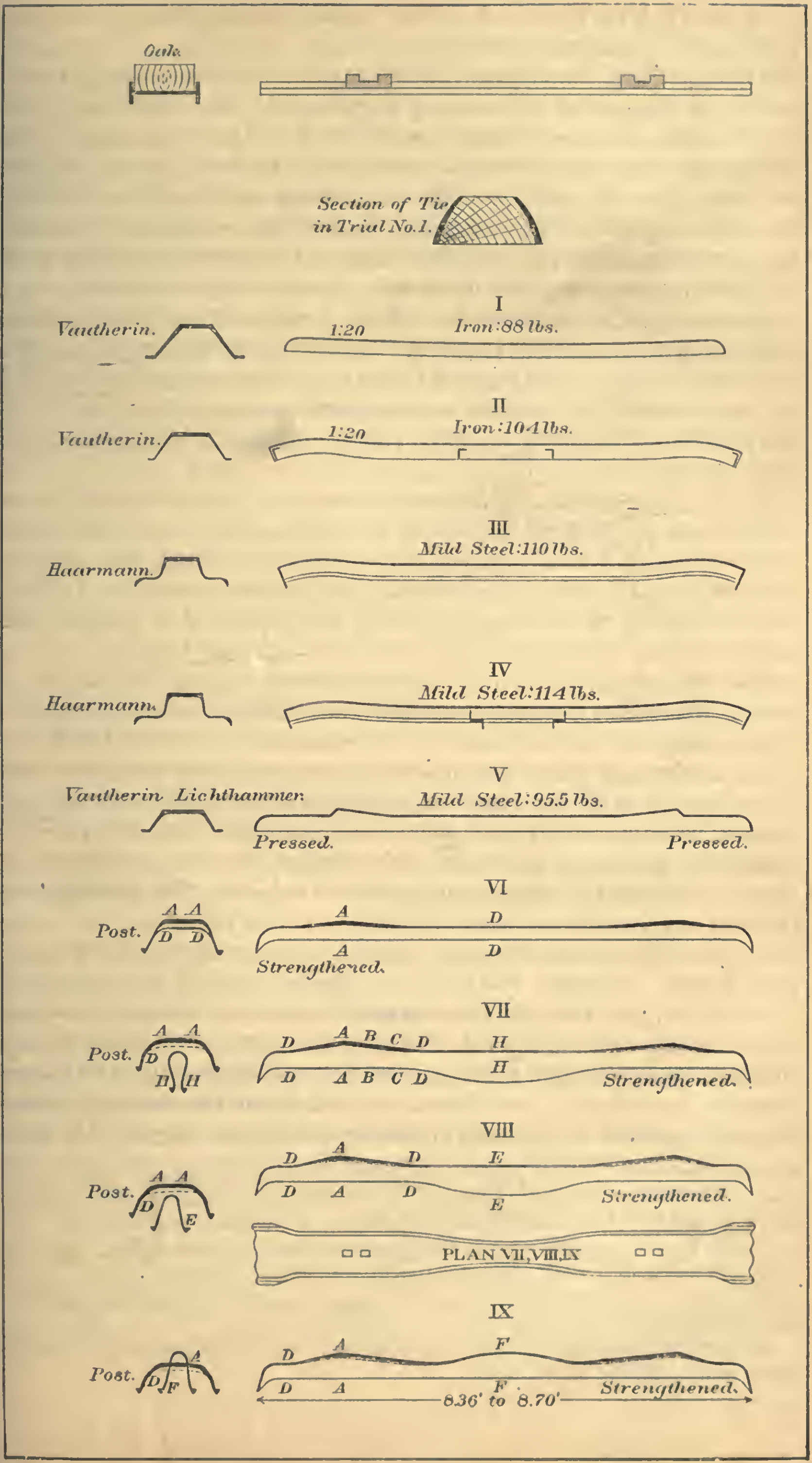
* For methods of calculation see Bulletin I of Forestry Division; also the valuable report of the American Society of Civil Engineers, June, 1885, on the "Preservation of Forests."

† Many important improvements introduced since have increased the advantage of metal over timber.

‡ Other railroads have, to their great satisfaction, followed this example. A total of about 457,300 ties (about 23,800 tons) of the Post types VI, VII, VIII, and IX is now in service on different lines of Holland, Belgium, France, Germany, Switzerland,


Oak.
Section of Tie in Trial No.1.
I
Vautherin.
1:20
Iron:88 lbs.
II
Vautherin.
1:20
Iron:104 lbs.
III
Haarmann.
Mild Steel:110 lbs.
IV
Haarmann.
Mild Steel:114 lbs.
V
Vautherin Lichthammer.
Mild Steel:95.5 lbs.
Pressed.
Pressed.
VI
Post.
A A
D D
A
D
A
D
Strengthened.
VII
Post.
A A
D
H H
D A B C D H
D A B C D H
Strengthened.
VIII
Post.
A A
D E
D A D E
D A D E
Strengthened.
PLAN VII,VIII,IX
IX
Post.
A
D F
D A F
D A F
Strengthened.
8.36' to 8.70'

Types VI, VII, VIII, and IX are in mild steel rolled to a variable section, strengthening at rail seats and tilt 1 in 20 being obtained directly by rolling, thus preserving the steel from damage at the vulnerable spot (rail seats) by bending or pressing. These ties weigh 50 to 55 kilograms each, corresponding to 57 to 63 kilograms per tie of uniform section BB (economy 15 per cent.). Type VI, without the narrow waist, like all preceding types, had not quite the same stability as the later types with narrow waist; indeed, this reduction of breadth in the middle causes the principal reaction of the ballast to work at the rail seats, eliminating the balancing action of the track which takes place when the support is in the middle, particularly on badly ballasted roads or with neglected packing. Moreover, the increased height at the center gives greater rigidity to the tie. The wedge waisted tie VII is, unfortunately, of difficult manufacture, and so types VIII and IX are practically esteemed the best, and all agree that they give remarkable results.

The ends are closed and project downward 2 inches into the ballast. The tests prescribed for inspection are very severe. The author executed a series of tests to ascertain whether annealing the ties after punching the holes does pay or not; his conclusion was, that with mild steel annealing is not necessary, but is desirable if it can be done at small expense.

The ties are tarred if they have to remain a long time beside the track. The price, including two years of guaranty, varies from $22 to $26 per ton.

The fastenings show the following improvements, gradually introduced and tried by Mr. Post. The surface of nuts and clips is roughened to facilitate the grip of the Verona nut-lock. The clips, if rolled (mild steel annealed), get three fillets for the same reason; if stamped (iron or mild steel), they are indented like the nuts. In both cases the clip has a large contact with the surface of the tie in order to reduce the wear. For the same reason the head of the bolt (iron or soft manganese steel) is large. The bolt must not be less than ⅞ inch diameter. The collar of the bolt, which is eccentric, to enable widening of gauge on curves by turning the bolt 180 degrees, fits tight into the tie hole; this hole being rounded in the corners to avoid cracks, the bolt collar is rounded accordingly. The Verona nut-locks are of the very best quality, severely tested as to elasticity and sharpness of points, and are guaran-

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and Asia (colonies). About 272,700 more (about 12,700 tons), comprising the narrow-gauge and rack-road ties for Sumatra, are ordered and being manufactured now, making a total of about 730,000 ties (or 36,500 tons). See on this subject:

(*a*) Mr. Bricka's official report to the French minister of public works.

(*b*) Mr. Kowalski's official report to the Milan Railroad Congress, 1887.

(*c*) Report of Vincennes Exhibition, 1887, highest award to Netherlands State Railroad Company and to the writer.

(*d*) Annual Report, 1887, of the French Society for the Advancement of Industry; silver medal awarded to the writer.

teed. The price of these improved fastenings does not exceed 24 cents per tie.

The statistical results as to cost of maintenance gathered to January 1, 1888, on twenty-four trial lengths, are shown in the accompanying table. Columns 1 to 14 give the particulars of sections, condition of laying, types, etc., and columns 15 to 22 the expense of maintenance per day and per kilometre in francs.

The statistical data gathered to January 1, 1887, and the close and scrupulous observations of the trial divisions, allowed the company to report seventeen conclusions to the Milan Railroad Congress in 1887.

The service from January 1, 1887, to January 1, 1888, having fully confirmed the opinions of the company on these seventeen points, the following conclusions are still applicable to the statistical data gathered to January 1, 1888, as contained in the accompanying table:

(1) Trials 11 and 14 are on curves of 350 metres radius and 16 millimetres per metre grade. Oak ties occupying this place previously had to be respiked every year, causing great cost of maintenance; the rail flange cut the spikes 3 to 4 millimetres, thus giving every year a gauge widening of 6 to 8 millimetres. Several ties of type III, on the contrary, taken from the track for inspection after 1,553 days of service, showed only a widening of 2 millimetres, the exterior bolts (of the old type "A") being worn only 1 millimetre by the rail flange. The tie surface only showed a slight amount of corrosion, and the holes were not in any way enlarged or ovalized. Considering the unfavorable conditions under which these ties were, these are very good results; in no year did the expense amount to 2 francs per day kilometre, and the average day kilometre is only 1.39 and 1.40 francs (columns 18 to 22).

(2) Trials 3 and 9 being on marshy ground, the result may also be considered as favorable; in no year as much as 2 francs per day kilometre, and average day kilometre 0.95 franc and 0.88 franc (columns 15 to 22).

(3) As to consolidation (about 2,300 days), the only trials comparable to the base trial No. 1 (oak ties) are trials 2, 3, 4, and 5. Though two of these four trials are under unfavorable conditions, there is no sensible difference between the average day kilometre of trials 2, 3, 4, and 5, and the day kilometre (0.605 franc) of trial 1, a very favorable result indeed, considering the following facts:

(*a*) Type I is now considered a poor system, each of types II to IX being great improvements. Had one of the more perfect types been used on these trials, still better results would have been obtained.

(*b*) Respiking and re-adzing of the oak ties of trial 1 had begun in 1886, and has to be continued in 1888 and following years, increasing the cost of maintenance with the age of the wood.

(*c*) With the trials on metal ties, on the contrary, there is a tendency shown of a decrease of expense as the permanent way becomes set.

(*d*) On trial 1 only ten oak ties had to be replaced by new ones since 1881; this renewing, however, will go on increasing with the age of the wood, thus increasing, apart from the cost of purchase, the daily expense (work) of trial 1. The renewal of ties on the other twenty-three trials, on the contrary, was *nil* since 1881 (not one metal tie being broken), and will be *nil* for many years.

(4) The day kilometre of trials 6, 7, 8, 12, and 17 does not exceed 0.88 franc; those of trials 10, 13, 15, 16, 18, and 19 are below 0.60 franc, though these eleven trials date only from 1883 and 1884.

(5) The time of observation for types VI, VIII, and IX (trials 20 to 24), has been too short to form any definite idea of the mean day kilometre; meanwhile everything tends to show that these types will give even better results than types I to V.

(6) The average expense for laying and maintaining the twenty-three trial-lengths 2 to 24, has not been greater than would have been occasioned by the timber ties laid on the same places. The supplementary expenditure for these trials, apart from the trouble of statistics, etc., is therefore *nil*.

The close observation of the permament way and of the manufacture of ties and fastenings led the company to the following conclusions:

(7) A part of the road near Liége, twenty-five trains daily, curve of 530 millimetres radius, 16 millimetres per metre gradient, after having been carefully packed, was left for forty months without any other work than occasional nut-tightening. This shows that a good road, with steel ties, once properly packed, requires no more scrupulous attention and maintenance than one laid with timber ties; on the contrary, it would have been dangerous to have left a track situated as this was, and laid with timber ties, for a period of three and a half years.

(8) The diagrams of the self-registering gauge-measure show that the gauge is much more regularly kept on metal ties than on timber (even new oak) ties.

(9) The position of the rail, which often changes on timber ties, is not variable with the metal ties.

(10) The lateral displacement of the track is insignificant with metal ties, even on curves of short radius, providing that the tie is closed at the end.

(11) The breadth of the ballast bed may be made a little smaller with the narrow-waisted metal ties (types VII, VIII, and IX) than with ordinary metal or timber ties.

(12) The respiking and re-adzing of trial No. 1 necessitated to 1888 the replacing of two bearing plates and 1,081 spikes by new ones. The renewal of fastenings on the metal ties is insignificant, especially with the adopted type "C."

(13) Iron is not recommended for metal ties; mild steel is superior to it in every respect, viz. manufacture, inspection, rigidity, and durability.

(14) Alternating joints have given satisfactory results, especially in curves of short radius.

(15) Suspended rail joints have given the best results on metal ties, providing the angle splice-bars be strong and the distance between joint-ties small.

(16) Types VII, VIII, and IX fulfill all conditions for properly imbedding the tie in the ballast. If the packing is done properly, and does not exceed 1½ feet from each side of the rail, the track can never become balancing, through the ballast working towards the middle of the tie and leaving the ends unsupported, for the shape of the tie drives the ballast towards the rail seats, both transversely and longitudinally. Generally the ballast soon forms into a compact cake, adhering to the interior of the tie, thereby augmenting both the base and the mass of the track.

(17) The track men, who generally abhor novelties, have soon learned, owing to practical instructions, to appreciate the steel ties and to make an excellent track with them.

The company closed these seventeen conclusions by quoting at the Milan Congress the following statement from the annual report of Mr. Charles Renson, resident engineer of the Liegeois section, which will be received with great appreciation on account of the distinguished and impartial manner in which this engineer has organized the trials of metal ties on that section:

> A single track with ties, Type VIII or IX (latest form), having twenty-five trains per day with curves, gradients, ballast, etc., as the Liege-Hasselt section, can be, after four years of consolidation, maintained in proper order at the rate of one hundred working days per year—kilometre. A gang of four men, working two hundred and fifty days a year, of which fifty days are given to other work, are able to maintain in good condition 8 kilometres of permanent way.

The Netherlands State Railroad Company, having experienced the great advantage of practical experiments made on trial sections of track, has continued experiments as follows, in order to gather information on other points:

Between Tilburg and Breda, four parts of equal length were laid in 1886 on the same track, to compare the cost of maintenance and of renewal between: (1) Ordinary steel rails (33 kilograms per meter) on timber ties. (2) Heavy steel rails (40 kilograms per meter) on timber ties with two Post's steel, toothed bearing-plates on every tie. (3) Heavy steel rails (40 kilograms) on heavy Post steel ties. (4) Ordinary steel rails (33.7 kilograms per meter) on ordinary Post steel ties.

The time of observation is yet too short for any conclusion.

Between Tilburg and Breda, four parts of equal length are being laid now in the same track to compare the cost of maintenance and of renewal between: (1) Ordinary steel rails on ten timber ties per 9 meters of track. (2) Ordinary steel rails on eleven timber ties per 9 meters of track. (3) Ordinary steel rails on twelve timber ties per 9 meters of track. (4) Ordinary steel rails on twelve timber ties per 9 meters of track, with alternating joints.

Between Weurne and Helmond the same four comparative trial lengths are being laid on ten, eleven, and twelve Post steel ties per 9 meters of track.

The information gathered by these methodical researches will be of great value, not only for the Netherlands State Railroad but for railroading generally; the best remedy for scanty net earnings being a reduction of the expenses of maintenance and renewal.

Cost of maintenance on trial tracks with wooden and metal ties, Netherlands State Railroad Company.

Trial number.	Trains per day.	Section of line.	From—	To—	Gradient in milimeters per meter.	Radius of curves in meters.	Length of trial in meters.	Number of ties.	Types.	
									Ties.	Fastenings.
	1	2	3	4	5	6	7	8	9	10
			Kilom.	*Kilom.*						
1	25	Liége-Tongres	15.620	14.612	12.0	500	1.008	1,120	Oak.	Spikes.
2	25	do	16.666	15.620	12.0	750 straight.	1.046	1,133	I.	A.
*3	25	Bilsen-Hassett	41.093	40.170	1.2	straight.	0.923	1,000	I.	A.
6	25	Liége-Tongres	7.946	7.432	16.0	1,000	0.514	600	II.	B.
7	29	Liers-Flamalle	1.831	1.393	level.	1,000	0.438	500	II.	B.
8	25	Tongres-Bilsen	25.031	24.570	8.0	straight.	0.461	500	II.	B.
*9	25	Bilsen-Hassett	43.625	43.349	4.0	straight.	0.276	300	II.	B.
11	25	Liége-Tongres	3.790	3.640	16.0	350	0.150	201	II.	B.
12	25	do	12.707	12.528	13.0	500	0.259	300	II.	B.
14	25	do	4.002 3.640	3.790 2.836	16.0	350	1.016	1,328	III, IV.	A.
17	25	do	12.528	12.315	13.0	500	0.215	250	IV.	A.
21	25	do	4.412 4.765	4.302 4.748	16.0	530	0.117	200	VI.	C.
22	25	do	8.000	9.000	16.0	1,000	1.000	1,081	VI.	C.
4	14	Hassett-Wychmael	22.238	21.130	2.9	straight.	1.108	1,200	I.	A.
*5	14	Wychmael-Achel	32.673	31.940	3.4	straight.	0.733	800	I.	A.
10	14	Hassett-Wychmael	8.408	7.301	3.9	straight.	1.107	1,200	II.	B.
13	14	do	1.562	1.218	6.5	500	0.344	400	II.	B.
15	14	do	1.218	0.765	6.5	500	0.453	500	III, IV.	A.
16	14	Achel-Eindhaven	47.334	47.795	0.8	2,000	0.461	500	III.	A.
18	14	do	47.795	48.256	level.	straight.	0.461	500	IV.	A.
19	14	do	46.868	47.334	0.8	straight.	0.466	505	V.	A.
20	14	do	52.709	52.032	1.0	2,000 straight.	0.677	735	VI.	C.
23	14	do	57.342.50	56.425.9	1.0	2,000	0.083.40	93	VIII.	C.
24	14	do	57.425.95	57.509.10	1.0	2,000	0.083.15	93	IX.	C.

* Marshy ground.

Cost of maintenance on trial tracks with wooden and metal ties, etc.—Continued.

Trial number.	When laid.	Date when observation commenced.	Days in service.		Cost of maintenance in francs per kilometer per day.							
			From beginning observation to January 1, 1888.	1887.	1881.	1882.	1883.	1884.	1885.	1886.	1887.	Average from beginning observation to January, 1888.
	11	12	13	14	15	16	17	18	19	20	21	22
1	1881	July 1, 1881	2,375	365	0.159	0.217	1.226	0.396	0.493	1.101	0.423	0.605
2	1881	....do	2,375	365	1.120	0.423	0.576	0.195	1.086	0.538	0.842	0.650
*3	1881	Sept. 1, 1881	2,313	365	1.930	0.829	1.881	0.256	0.901	0.383	1.135	0.952
6	1882	Jan. 1, 1883	1,826	365	....	....	1.214	0.489	0.638	1.112	0.552	0.801
7	1882	....do	1,826	365	....	....	1.582	0.277	1.160	0.494	0.573	0.817
8	1882	....do	1,826	365	....	....	1.676	0.533	1.253	0.118	0.046	0.725
*9	1882	....do	1,826	365	....	....	1.687	0.861	0.953	0.278	0.625	0.881
11	1883	Oct. 1, 1883	1,553	365	....	....	0	1.084	1.974	1.187	1.660	1.389
12	1885	.. do	1,553	365	....	....	0	0.831	0.465	0.264	0.746	0.587
14	1885	...do	1,553	365	....	....	0	1.647	1.792	0.867	1.610	1.392
17	1883	....do	1,553	365	....	....	0	1.132	1.111	0.498	1.000	0.879
21	1885	Apr. 1, 1885	1,005	365	....	....	....	....	0.036	0.078	0.983	0.495
22	1887	June 1, 1887	214	214	....	....	....	....	....	....	0	0
4	1881	June 15, 1881	2,390	365	0.0635	0.595	0.614	0.198	0.156	0.418	0.297	0.407
*5	1881	Sept. 1, 1881	2,313	365	1.584	1.027	0.790	0.326	0.536	0.569	0.227	0.632
10	1882	Jan. 1, 1885	1,826	365	....	....	1.077	0.475	0.329	0.503	0.595	0.596
13	1883	Sept. 15, 1885	1,569	365	....	....	0	0.433	0.438	0.879	0.583	0.513
15	1883	. do	1,569	365	....	....	0	0.246	0.412	0.258	0.429	0.313
16	1883	Mar. 1, 1884	1,401	365	....	....	....	0.311	0.143	0.329	0.802	0.421
18	1884	....do	1,401	365	....	....	....	0.290	0.372	0.553	0.651	0.471
19	1884	....do	1,401	365	....	....	....	0.551	0.897	0.277	0.492	0.554
20	1885–'86	June 1, 1886	579	365	....	....	....	....	....	0.144	0.252	.212
23	1887	Sept. 1, 1887	122	122	....	....	....	....	....	....	0	0
24	1887	.. do	122	122	....	....	....	....	....	....	0	0

* Marshy ground.

REMARKS.—These trial-lengths are on single-track road. First group, 25 to 29 trains per day; second group, 14 trains per day. Rails, 38 kilograms per meter; steel angle splice bars. Ballast—gravel, sand, and cinder. Heaviest engine on these lines, 50 tons, with 13½ tons on the heaviest axle; heaviest engine on other lines, 68 tons, with 13.9 tons on the heaviest axle. Speed up to 50 miles per hour (on some parts 60 miles per hour). A day's maintenance per man costs 2.19 francs; the results of columns 15 to 22 may be transformed into days by dividing by 2.19. The figures in columns 15 to 22 give the expense for work of maintenance, not the expense for purchase of new spikes, bolts, etc. Not one of the metal ties in this table, nor of the 124,000 steel ties in use on other lines of the Netherlands State Railroad Company, has broken in the track.

DISCUSSION.

E. E. Russell Tratman, Jun. Am. Soc. C. E.—Having received from Mr. J. W. Post, only a few days before the convention, the paper on "Maintenance Expenses of Track with Steel and Wooden Ties on the Netherlands State Railroad," which I have transmitted to the society by request of Mr. Post, I had not time to give as much attention as I would like to have done to this discussion.

The subject of metal railroad ties is one in which I take very much interest, and for some time past I have been engaged in making extensive investigations and collecting information with regard to practice and experience in foreign countries. In making my investigations I have been surprised at the great extent to which metal ties have been actually adopted for service, for while I knew that experiments had been made in many countries, in some cases on a quite extensive scale, I had no idea that, as a result of some of these experiments, many railroads had practically adopted these ties for regular use; this, however, I found to be the case, and several European railroad companies are now gradually substituting metal for wooden ties on their systems. I think few engineers who have not paid especial attention to this matter realize that metal ties are in actual service, the general impression seeming to be that while many experiments have been made and are still being continued, yet that no practical results have been obtained. To this lack of appreciation of the results of foreign experience may be attributed to a considerable degree, I think, the general indifference of American engineers to the question of metal track. The fact that the question of the future timber supply is one of serious import does not seem to be realized, although the reports of the forestry division of the United States Department of Agriculture show that use and waste are playing havoc with a supply that cannot, under the present system (or want of system) of forestry in this country, be renewed in proportion to the demand. It has always seemed to me surprising that American engineers, who are usually in the van of any great step in the profession, should have paid so little attention to this very important matter; important both as to the financial economy and the practical efficiency of the track. In my opinion steel ties should be used as the standard for first-class track, and not merely as a substitute for timber when the latter becomes scarce or expensive. For instance, on such a road as the projected New York and Boston Rapid Transit line, which is intended to be an independent line, and which will probably, when it materializes, start out with a heavy and rapid traffic, steel ties should be laid down in the first place. The same holds good for existing trunk lines, on which steel ties should be introduced, as an advancement in railroad engineering and a step towards economy.

Taken as a whole, the results of experience have been satisfactory, and the type which has been found to be the best is the cross-tie of the familiar reversed trough section. Cast-iron "bowl" sleepers are much used in new countries, and longitudinal iron sleepers are still used to some extent in Austria and Germany, but the cross-tie of trough section is the best type, as has been proved by experience and careful tests. In consequence this form of tie is being more and more widely adopted, numerous variations of section and various styles of rail fastenings being used, in accordance with the ideas of different engineers. In England several railroads are using steel cross-ties to a greater or less extent, but in consequence of the engineers keeping to the double-headed rail in chairs the track is very complicated and expensive, representing money wasted and lying idle in much useless metal, whereas with a good flange rail a metal track might be obtained more economical and more efficient than the present style of rails and chairs on wooden sleepers. Experience has shown that the ends should be closed, but in quite a number of cases open-end ties are used. With open ends, of course, the ties are more liable to lateral displacement, as they do not present the area of resistance presented by a wooden tie or a closed end.

As will be seen by Mr. Post's paper, the Netherlands State Railroad Company has made a systematic series of trials of different types of metal ties, and the very valuable and important result of these trials has been the designing of the mild steel rolled tie of trough section, with varying thickness, now well known as the "Post" tie, which has been adopted to a very considerable extent on European lines. Mr. Post has been fortunate in having charge of a road owned by a progressive and far-seeing corporation, which has grasped the economic purposes of metal track, and encouraged its engineer in his work of investigation. The comparisons of the different systems were gone into most thoroughly, account being taken of the amount of labor, time, and expense involved in maintenance, renewals, and repairs, and therefore Mr. Post has been able, gradually but steadily, to improve the form of tie, until he has arrived at the present form, which is correct in theory and successful in practice; it is easily manufactured, and has proved in service its advantages in point of economy and efficiency. The trouble experienced with early forms of ties was that they failed by cracking, generally between the holes for rail attachments, and if made thick enough to prevent cracking they were too heavy and expensive. With the "Post" tie the thickness is increased at the rail seat, giving ample strength where required, but without any undue excess of weight. This strengthening is secured in the operation of rolling by the use of special machinery, and in the same operation is secured the inclination of the ends which gives the rails an inward cant of one in twenty, in accordance with European practice. Many European steel works have orders on hand for "Post" ties.

The question of rail fastenings is one almost as important as that of the type of tie, and many different plans have been tried, some simple, but the majority very complicated. All riveting causes an extra expense, but a very favorite plan is to have a "clamp" or "crab" riveted to the tie to hold one side of the rail flange, the other side being held by a bolted clamp. Mr. Post, realizing that all extra shop-work is necessarily expensive, has adopted bolts exclusively, with entirely satisfactory results. It will be noted that the first type of metal tie experimented with had wooden blocks for the rails to rest upon, the idea being that the rail required an elastic seat. This seriously impaired the general efficiency of the tie, for the wood rotted and gave constant trouble, so that this form of tie was soon abandoned. It has been conclusively proved by experience with various types of ties in different countries that such a wood-bearing is not only unnecessary, but a positive disadvantage, and that the track is satisfactory to railroad men and travelers when the rail is fastened directly on the metal tie, and therefore no wood should be used at all, but a metal track should be entirely of metal. The introduction of metal ties has been hampered by the attempt to secure a "cheap" tie. The objects in using metal are to obtain economy in maintenance and efficiency in operation, and neither of these objects can be obtained by using a tie which is "cheap." Every desirable feature can not be combined in one piece of steel, and if the tie is to make the track safer, reduce the maintenance expenses, keep the road in better condition, and far outlast the wooden tie, it must have sufficient metal to insure these advantages. You need to have, and to pay for, enough metal to make an efficient tie; but you need not have, and need not pay for, extra metal that is mere dead weight. With ties, as with rails, the design and manufacture are equally as important points as the weight, and the rail fastenings no less important.

Two points need to be considered in designing or adopting a metal track, viz, economy and simplicity. Cheapness is very far from being economy, being in fact directly opposed to it. Simplicity is necessary, both for economy and efficiency, as the track which, while possessing ample strength, is the most simple in its construction, will give the least trouble, and consequently involve the least expense for maintenance. A good metal track, once well laid, is in itself a source of economy in maintenance and operation, and it is to be hoped that this type of track will soon be a feature of first-class American railroads.

In nearly every large country but America, and in many of the smaller countries, metal ties have been experimented with, and I would strongly urge that more practical attention should be paid to so important a matter by American engineers, railroad men, and steel manufacturers.

At the International Congress of Railroads, September 17 to 24, 1887, the following resolutions were the outcome of its discussions:

(*a*) The opinion of the Brussels Congress that iron ties are of equal value to wooden, has not been negatived during the last two years; the application of iron ties is rather on the increase.

(*b*) The question whether the use of wood or metal ties is cheaper depends on the local conditions and the state of the iron market.

(*c*) Regarding cost of maintenance and renewal, not yet sufficient data are on hand for lines with large and rapid traffic; for medium traffic and slow trains the iron ties offer advantages, especially when after some time the track has consolidated and the fastening has settled well.

(*d*) For the "Vautherin" form the use of a homogeneous metal is desirable.

PATENTS RELATING TO METAL RAILWAY TRACK.

By E. E. Russell Tratman.

The following list of United States patents relating to metal railway track will be found useful by persons interested in this subject. It could not practically be made anything more than a descriptive index, giving sufficient information to enable any one who wishes to investigate more fully to find the specifications.

No. 1,262; date, July 26, 1839; J. Stimpson.—Transverse frames resting on longitudinal timbers, with inclined braces to hold them in position, and sockets at the top to receive the web of a rail with a very narrow flange.

No. 16,898; date, March 24, 1857; H. Carpenter.—A short hollow post under each rail, connected by a tie-plate; T-shaped fastening fitting into hollow of post.

No. 18,494; date, October 27, 1857; S. A. Beers.—Continuous longitudinal structure with transverse tie-plates. Saddle rail of _∩_ section.

No. 19,704; date, March 23, 1858; S. H. Long.—Cross-ties of channel ┌┐ section or T section (the latter made of two angle irons). Continuous flat plate under ordinary rail.

No. 20,620; date, June 22, 1858; W. Bryent.—Combined longitudinal grooved rail and iron pavement.

No. 32,794; date, July 9, 1861; B. C. Smith.—Wide longitudinal channel sleeper and rail combined, with transverse rods. A raised rib lengthwise of the sleeper forms the rail.

No. 36,579; date, September 30, 1862; B. C. Smith.—Longitudinal cast-iron continuous bearing, of channel section, connected by transverse tie-rods. Rail secured to chairs.

No. 53,507; date, March 27, 1866; Franz Vester.—Flat cross-tie, with two deep corrugations along its whole length. Ends turned down.

No. 66,711; date, July 16, 1867; R. M. Holland.—Cross-tie of λ section. Flange cut away for rails. Hinged wedge fastening.

No. 70,731; date, November 12, 1867; Henry McCan.—Broad flat transverse base-plates, with longitudinal girders held together by tie-rods. Rails resting on top of girders.

No. 71,063; date, November 19, 1867; Leonard Repsher.—Wrought-iron flat cross-tie, bent up at ends to embrace flange and web of rail, angle-clamp bolted to tie on inside of rail. Bolt through clamp, web of rail, and end of tie.

No. 83,880; date, November 10, 1868; J. Potter.—Flat transverse base-plate, with two uprights which support continuous stringers, to which flangeless T-rails are bolted.

No. 109,504; date, November 22, 1870; C. Fisher.—Cross-tie of inverted trough section, with closed ends. Two pockets for wooden bearing-blocks. Rail fastened by flat plates resting on tie and rail flange, screwed to the wooden blocks.

No. 112,805; date, March 21, 1871; S. M. Guest.—A railway joint chair, combined with an iron cross-tie of T section.

No. 121,956; date, December 19, 1871; J. Newton.—A rail-fastening for iron ties. Flat tie with end turned up; wooden wedge between rail and end of tie; vertical gib and cotter fastening (with serrated cotter) on inside of rail.

No. 123,526; date, February 6, 1872; L. E. Towne.—Cylindrical cross-tie with a flat base plate at each end, and a rail chair on top at each end, secured by a strap passing round the tie.

No. 124,521; date, March 12, 1872; R. M. Upjohn.—Longitudinals under each rail, of ⊥ section with very high vertical web. The rail is of ⊓ section and rests upon the flanges of channel irons bolted to the vertical web of the longitudinals.

No. 134,418; date, December 31, 1872; James Calkins.—The continuous longitudinals of channel sections have lugs to hold the outer flange of rails; transverse plates project over the inner flange and are bolted to the longitudinals.

No. 136,067; date, February 18, 1873; J. W. Kern.—A continuous roadbed of ∧ section, with the rails laid on the horizontal flanges. Transverse base plates at intervals. The bed to be of $\frac{1}{4}$-inch boiler-iron.

No. 139,518; date, June 3, 1873; W. Peck and H. C. Richman.—Two chairs connected by a horizontal flat tie-plate. Wooden bearing-blocks in the chairs.

No. 140,411; date, July 1, 1873; C. W. Gulick.—A flat wrought-iron cross-tie with ribs to form a channel for the flange of the rail. Fastenings of iron $\frac{1}{16}$ inch diameter under tie, passing up through holes in the same, with ends bent over rail flange. Ties about 5 inches wide and $\frac{1}{2}$ inch thick.

No. 143,407; date, October 7, 1873; P. S. Devlan.—A cross-tie made of two iron plates on edge, fastened together at the middle and widening out to hold a wooden block at each end.

No. 144,207; date, November 4, 1873; George Keech.—Longitudinal plates under each rail, with lugs to hold outside of rail flange. Tranverse tie-plates project over the inner flange and are secured by horizontal bolts passing through lugs on the base plate.

No. 145,991; date, December 30, 1873; H. L. De Zeng.—Wrought-iron cross-tie of ⊓, ¯∪¯∪¯, or other section. A clip stamped out of the metal holds outer flange of rail; loose clip secured by vertical key or cotter holds inner flange. (See 155,369.)

No. 146,376; date, January 13, 1874; G. H. Blaisdell.—A cast-iron cross-tie of ∧ section with wide, flat, deep ends, having sockets for wooden blocks. A bolt passes through both blocks and the whole length of the tie.

No. 147,563; date, February 17, 1874; P. Kendrick and J. Stokes.—A cross-tie made of two old rails laid parallel, with a wooden block between them at each end, and base plates if desired.

No. 148,242; date, March 3, 1874; George Potts.—Continuous bearing of wood held between two continuous iron stringers of ⊥ section, the top of the web being bent over to hold the rail flange. Bolts pass through the three pieces.

No. 155,369; date, September 29, 1874; H. L. De Zeng.—A cross-tie of inverted trough section, with open ends, but with projecting wings at ends to prevent lateral displacement. See No. 334,696.

No. 163,187; date, May 11, 1875; S. H. Hamilton.—An iron or steel cross-tie of square hollow section throughout, or only at ends. Fixed lugs hold the inner flange of rail, and bolted plates hold the outer flange.

No. 163,254; date, May 11, 1875; H. Reese.—A rolled iron cross-tie of T section; lugs stamped out while hot from the rolls. Bent clip and horizontal wedge fastening for outer flange of rail. (See 214,192.)

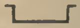
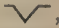
No. 164,793; date, June 22, 1875; Ramon Bañolas.—Cross-ties of I section, carrying longitudinal stringers of ⊥ section, to which flangeless rails of ⌉ section are bolted.

No. 166,625; date, August 10, 1875; R. E. Nichols.—A continuous hollow bearing, section similar to lower half of letter A; bottom closed; top open, with horizontal flanges to carry the rail flange; cross-ties of ⊔ section. Longitudinals and cross-ties filled with broken stone.

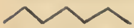
No. 171,422; date, December 21, 1875; John Quigley.—A cast-iron cross-tie with chair combined, for street railway track.

No. 172,041; date, January 11, 1876; E. E. Lewis.—A cross-tie of + section, with the top vertical flange cut away for the rails, which are secured by wedges. (See 183,766.)

No. 176,213; date, April 18, 1876; George D. Blaisdell.—A cast-iron cross-tie, with wide ends and loose bearing blocks, all held together by a bolt running through the whole length of the tie.

No. 182,984; date, October 3, 1876; Leonora E. Yates.—Cross-ties of , , or section, the latter being semi-cylindrical, with flanges. The rails are fastened by bolted clamps.

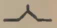
No. 183,766; 183,767; 183,768; date, October 31, 1876; E. E. Lewis.—A cross-tie of + section; rails of different forms. Also a joint tie of ⊥⊥ section. (See 172,041.)

No. 185,808; date, December 26, 1876; D. S. Whittenhall.—A cross-tie of  section; the rails resting in notches in the top ridges.

No. 188,087; date, March 6, 1877; H. S. Wilson.—A cross-tie of I section, with fixed and movable rail clips.

No. 188,710; date, March 20, 1877; N. S. White.—A continuous bed-plate under each rail, with cross-ties.

No. 190,739; date, May 15, 1877; A. H. Campbell.—A cast-iron cross-tie, with sockets for wooden bearing-blocks.

No. 192,842; date, July 10, 1877; A. W. Serres.—A continuous bearing of  section (in two pieces) under each rail, with transverse tie-bars. The web of a flangeless rail lies between the two vertical webs. (This track has been used in Europe. See Engineering News, New York, January 29, 1887, page 73; also Railroad Gazette, New York, August 19, 1887.)

No. 198,060; date, December 11, 1877; John B. Ward.—A longitudinal iron pipe (for conveying water) under each rail; the bottom of rail curved to fit pipe.

No. 198,464; date, December 25, 1877; E. E. Lewis.—A cross-tie consisting of an old rail with two notches cut to the level of the flange to admit the track rails. Two rails with wooden bearing-blocks used at joints. (See 172,041.)

No. 198,618; date, December 25, 1877; D. Horrie.—A transverse truss of cast or wrought-iron. Horizontal hook-bolt fastenings.

No. 201,667; date, March 26, 1878; H. A. Haarmann.—Continuous bearing for each rail, with cross-ties. This track has been extensively used in Europe. (See Engineering News, New York, January 29, page 74.) (See 219,856.)

No. 206,647; date, July 30, 1878; T. W. Travis.—A hollow cross-tie, with boxes at the ends open on top. The rails are held between two ⊏ clips; the groove holds the rail-flange; the upper web lies against the rail web, and the lower web is wedged into the box.

No. 207,242; date, August 20, 1878; J. A. Bonnell.—An inverted trough cross-tie, with closed ends and corrugated top. Bolted clips or angle-bar fastenings for rails.

No. 207,320; date, August 20, 1878; J. H. Thompson.—A cross-tie made in two pieces, dove-tailed together in the middle. The rails rest on wood blocks.

No. 207,719; date, September 3, 1878; W. E. Curtiss.—A wrought-iron cross-tie of inverted trough section with flaring sides, having a brace of the same section inside under each rail. The ends are open. Rails secured by bolted clips.

No. 210,774; date, December 10, 1878 (patented in Germany, January 18, 1878); F. B. Freudenberg.—A wrought-iron cross-tie of somewhat similar section to the preceding one. Hooked clips are riveted on for the inside and outside flange on alternate ties, the rails being sprung into place. Long ties for double tracks.

No. 214,192; date, April 8, 1879; H. Reese.—A cross-tie of T section, with the ends of the horizontal table turned down at an angle. Clip and wedge fastening. (See 163,254.)

No. 215,675; date, May 20, 1879; H. Reese.—Improvements upon the preceding one.

No. 216,846; date, June 24, 1879; L. A. Gouch.—A cross-tie of —|— section, the longitudinal web being the widest and having its edges turned up or down.

No. 218,559; date, August 12, 1879; S. Nicholls (of England).—A continuous broad bed-plate under each rail, for street railways. The rail is formed of two channels, leaving a space between for the wheel flange ⊐ ⊏.

No. 218,603; date, August 12, 1879; A. P. Whiting.—A cross-tie of ⊢⊣ section, the top flange cut away for the rails. Bolted clips hold the inner flanges of rails.

No. 218,648; date, August 19, 1879; C. F. Wagner (of Austria).—A cross-tie composed of two parallel pieces of T section, fastened together by cross-strips. Bolted clip rail fastenings.

No. 218,878; date, August 26, 1879; C. Hanshaw.—A cross-tie made in two pieces lengthwise; on one piece are clips for the inner flange of one rail and the outer flange of the other, and on the other piece are clips for the outer and inner flanges, respectively. The two pieces are held together by a flat horizontal key driven between other clips in the middle of the tie.

No. 219,856; date, September 23, 1879; H. A. Haarmann, of Prussia, (see No. 201,667).—A cross-tie of inverted trough section with flaring sides, and a flat or grooved top table. The rail fastenings are ⊏-shaped, with a bolt passing under the rail.

No. 220,026; date, September 30, 1879; H. T. Livingston.—A tubular cross-tie of oval section with a flat surface under each rail. Rails fastened by bolts screwed into the tie. Interior of tie packed hard with straw, grass, etc.

No. 221,596; date, November 11, 1879; O. E. Mullarky.—A cross-tie of channel section ┌─┐ with wooden bearing blocks wedged inside under the rails. The rails are fastened by bolted clips.

No. 223,187; date, December 30, 1879; J. R. Sullivan.—Two separate cast-iron bearing pieces connected by a tie-bar. Each rail is secured by a cast-iron wedge.

No. 226,308; date, April 6, 1880; A. Greig (patented in England March 25, 1879).—Flat cross-ties with one or two grooves along the whole length. A brace or clip is riveted to hold the outside of the rail, and the rail is held against it by a hook bolt, the body of which lies in the groove and has a nut at the end of the tie. (This system is much used for portable railways manufactured in England.)

No. 227,602; date, May 11, 1880; D. S. Whittenhall.—Improvements on No. 185,808.

No. 9,292 (re-issue); date, July 13, 1880; H. Reese.—See original number 214,192 of April 8, 1879.

No. 230,826; date, August 3, 1880; Lewis Scofield.—A cross-tie of ⎍ section. Riveted and bolted clips for rail fastenings.

No. 231,755; date, August 31, 1880; William Brown.—A hollow cross-tie of rectangular section, with concave bottom and open ends. A rib at the ends keeps the rail in position, and it is fastened down by hooked bolts with nuts inside the tie.

No. 233,528; date, October 19, 1880; W. C. Lutz.—A cross tie of ⊥ section, with the rails secured by flat hooked clips bolted to the side of the vertical web. (See 241,389.)

No. 235,078; date, December 7, 1880; G. H. Gilman.—A cast-iron cross-tie of rectangular section, with grooves to reduce the weight. The rails are held by fixed and movable lugs.

No. 235,321; date, December 7, 1880; F. A. Williams.—The two broad bearing plates on which the rails rest are connected by two transverse tie-plates, placed on edge.

No. 240,987; date, May 3, 1881; I. W. Fleck.—A cross-tie made of an ordinary rail, head down, with strengthening sections and a broad base plate bolted to it. It is curved into an arch form, high in the middle, with the ends level for the track rails.

No. 241,389; date, May 10, 1881; W. C. Lutz.—A cross-tie of cylindrical form, with flat-bearing surfaces for the rails; or with a vertical web on top, with notches for the rails. (See 233, 528.)

No. 242,850; date, June 14, 1881; H. Thielsen.—Cross-tie of T section; in two halves, one under each rail. Bent clips formed out of the metal of the tie. The two pieces keyed together at the middle. (See 317,244.)

No. 246,888; date, September 13, 1881; G. A. Jones.—A cross-tie of ⊥ section with the ends formed into a chair. The rail is held in the chair and spiked to a wood block.

No. 247,248; date, September 20, 1881; Levi Haas.—A cross-tie made of an old rail with the ends resting on wood blocks; the track rails are secured to the top of the tie. (See 257,572.)

Nos. 249,270, 249,271; date, November 8, 1881; E. H. Tobey.—Cross-ties of ⊔ or V section; the rails are held in chairs resting on wooden blocks.

No. 249,503; date, November 15, 1881; J. Clark.—A cross-tie of semicircular section ⌒, the bottom fastened to a flat bed-plate the whole length of the tie. The top of the arch cut away for the rail. (See 256, 199, 259, and 095.)

No. 251,251; date, December 20, 1881; C. F. Kreuz.—A flat cross-tie with thickened ends to hold the outer flanges of the rails; and a flat cross-tie with another flat piece resting on it to hold the inner flanges of the rails. These ties placed alternately. (See 263, 919.)

No. 254,802; date, March 14, 1882; J. Conley.—A flat cross-tie in two pieces, with the inner end of each turned up so as to be bolted together. Under the rails the sides are turned down. Clips are stamped out of the metal. (See 332, 384.)

No. 255,554; date, March 28, 1882; F. A. Williams.—A cross-tie of shallow inverted trough section, with broad ends. The rails are held against fixed clips by plates the whole length of the tie, placed on edge, underneath, with a hooked end to hold the rail flange. These plates are secured by a horizontal key in the middle of the tie.

No. 256,199; date, April 11, 1882; J. Clark.—Improvements upon No. 249,503.

No. 257,437; date, May 2, 1882; H. De Zavala.—A cross-tie of Λ section, with U bolts passing under the rail and having nuts screwed down on the rail flange.

No. 257,572; date, May 9, 1882; Levi Haas.—A cross-tie consisting of two cast-iron bed-plates, with bearing blocks to which the rails are bolted. A tie-bar connects the two bed-plates.--See No. 247, 248, 315, 771, 389, and 464.

No. 259,095; date, June 6, 1882; J. Clark.—Further improvements on Nos. 249,503 and 256,199. (See 270, 637; also August 5, 1884, and 358, 144.)

No. 259,823; date, June 20, 1882; A. L. Cubberlery.—A flat cast iron cross-tie, with concave bottom, and dove-tail grooves on top for sliding rail-fastenings into place.

No. 259,891; date, June 20, 1882; J. H. Meacham.—A cross-tie of ⊥ section, with end boxes for wood blocks, to which the rails are secured by hook bolts.

No. 260,231; date, June 27, 1882; J. Parr.—A cast-iron cross-tie with fixed and movable lugs for the flanges of the rails. (See 277,333.)

No. 263,919; date, September 5, 1882; C. F. Kreuz.—A cross-tie of ⊢⊣ section, the rails resting on the web and secured by wedges. An improvement on No. 251,251.

No. 265,760; date, October 10, 1882; M. I. Cortright.—A cross-tie with two grooves or corrugations in its length, and with notches to receive the flange of the rails.

No. 267,930; date, November 21, 1882; G. L. Putnam.—A cross-tie of square section, hollow or solid, with hooked spikes put in place from the bottom and tapering upwards. (See 285,842.)

No. 269,442; date, December 19, 1882; R. B. Meeker.—Cross-ties of T section, with broad table. Flat horizontal bars with turned-up ends, used alternately with the ties. The rail to be of extra height, bolted to chairs

No. 270,637; date, January 16, 1883; J. Clark.—A flat cross-tie with arched bearing plates and chairs. See No. 259,095.

No. 272,850; date, February 27, 1883; T. Breen.—A flat cross-tie twisted spirally in the middle and having the ends turned up. (See 294,191.)

No. 274,309; date, March 20, 1883; W. H. Gibbs and George Snook.—A cross-tie of ⊥ section, with supports for a rail-chair of inverted-trough section, with a wooden block, to which the rail is secured by hooked clamps.

No. 276,414; date, April 24, 1883; E. B. Hungerford.—A cross-tie of shallow channel section ⊔. The flanges are cut away and notched to hold the rail-flange, and the rail rests on a loose bed-plate with a clip to hold the other flange; the plate being held in place by a horizontal key driven through holes in the tie-flanges.

No. 277,333; date, May 8, 1883; J. Parr.—A hollow cast-iron cross-tie. The rails are secured to loose chairs, having long projections which run nearly through the tie and are secured by a vertical bolt at the middle of the tie. (See No. 260,231.)

No. 280,110; date, June 26, 1883; S. B. Wright—A cross-tie of inverted-trough section, with the inside of the top arched. (See 298,539.)

No. 280,200; date, June 26, 1883; J. Mahoney and D. W. Shockley.—A cross-tie of ⊥ section, with wooden bearing-blocks. (See No. 370,631.)

No. 281,806; date, July 24, 1883; A. R. Spaulding.—A cross-tie of channel section ┌─┐ to which the rail is fastened by a series of flat horizontal keys or wedges in dove-tailed grooves.

No. 283,076; date, August 14, 1883; J. L. Chapman.—Cross-ties of shallow channel └─┘, or of two flat plates, one above the other, separated by distance-blocks. Each rail is secured by bolted clips to a bed-plate.

No. 283,230; date, August 14, 1883; H. F. Flickinger.—A cross-tie of I section, to which the rails are secured by ∩ bolts with the nuts on the under side of the top flange of the tie.

No. 284,157; date, August 28, 1883; J. W. Young.—A hollow, open-sided, elastic cross-tie of ⊐ section; to be filled with ballast or earth on surface lines. Two or more of these plates to be placed inside one another, with one side open, or to form a closed tie. It is claimed to be adapted to elevated roads.

No. 285,833; date, October 2, 1883; John Newton.—Channel-iron stringers ┌─┐ with flat cross-ties fastened to the top.

No. 285,842; date October 2, 1883; George L. Putnam.—A cross-tie of T section, depressed in the middle to hold a water-trough for supplying locomotives. The rails are secured by bolted clips. See No. 267,930.

No. 285,986; date, October 2, 1883; Clark Fisher.—A bent-plate cross-tie, of ∩ section in the middle, with flat ends. A U bolt passes under the rail, and washers are screwed down on the rail flange by the nuts.

No. 287,418; date, October 30, 1883; J. J. Clarke (of Peru).—A flat plate tie for portable railway track, with special joint fastenings. (Assigned to A. W. Colwell, New York.)

No. 289,806; date, December 11, 1883; T. J. Bronson and A. Armstrong.—An iron or steel cross-tie of approximately semi-cylindrical section ∩, with lugs struck up by means of dies.

No. 290,793; date, December 25, 1883; L. O. Orton.—A flat inverted trough cross-tie, with wedge-shaped boxes projecting above and below to hold the bearing blocks and fastenings.

No. 291,514; date, January 8, 1884; H. R. Holbrook.—A hollow cross-tie of oval section, with thickened portions under the rails; rails secured by bolted clips.

No. 292,421; date, January 22, 1884; J. J. Du Bois.—A cross-tie, with dove-tailed groove for rail and a wedge fastening.

No. 293,194; date, February 5, 1884; J. Reven.—A flat tie-bar to keep rails from spreading; one end bent up to hold rail, the other end having thread and nut, with movable clamp.

No. 293,302; date, February 12, 1884; George W. Bloodgood.—Bolted clips for fastening rails to ties of inverted-trough section.

No. 294,191; date, February 26, 1884; T. Breen.—A cross-tie made in two pieces, lengthwise; placed side by side, holding the rail-chairs and fastenings between them. (See 272,850.)

No. 296,725; date, April 15, 1884; W. T. Carter.—A hollow cross-tie, with flat top and bottom and concave sides.

No. 298,539; date, May 13, 1884; S. B. Wright.—Fastening rails to inverted-trough cross-ties by clips and T-headed bolts. (See No. 280,110.)

No. 299,557; date, June 3, 1884; J. Lockhart.—A clamp or tie-rod, to be used in connection with wooden ties. A tie-rod, running across the track, has clamps to hold the rail flanges, the inner clamps being held by set-screws. It is claimed that soft-wood ties can be used, as there will be no tendency for the rails to spread. (See 327,285.)

No. 302,965 and No. 302,966; date, August 5, 1884; C. S. Westbrook.—A cross-tie of ┌─┐ section, with parts of the horizontal table cut away. The rails are held by riveted and keyed angle plates.

Nos. 10,504, and 10,505 (re-issues); date, August 5, 1884; J. Clark.—Improvements in No. 249,503.

No. 303,373; date, August 12, 1884; E. G. Holtham (of England). Patented in England, December 22, 1883.—Broad longitudinals under each rail, with transverse tie-rods, and with additional side plates to increase the bearing on the ballast.

No. 304,746; date, September 9, 1884; G. W. B. Neal.—A cross-tie made of triangular section, with the rails carried in and bolted to chairs fastened to the apex of the tie.

No. 306,090; date, October 7, 1884; Robert Moffly.—A cross-tie made of three pieces the full length of the tie, bolted together so as to form a ⊥ slot along it, in which the rail fastenings slide.

No. 306,139; date, October 7, 1884; B. W. De Courcy.—A cross-tie of _∩_∩_ section, with the rails resting on the top and secured by hooked clamps bolted together below the rail.

No. 309,428; date, December 16, 1884; J. H. Williams.—A cross-tie of U section, with wooden blocks to which the rails are spiked.

No. 310,269; date, January 6, 1885; Abraham Gottlieb.—A cross-tie of inverted-trough section, with a groove along its top table. The rail is fastened by bolted clips or a special form of locking-plate or chair.

No. 312,566; date, February 17, 1885; W. H. Knowlton.—Cross-ties of different sections.

No. 312,717; date, February 27, 1885; E. N. Higley.—A flat cross-tie with sides and ends turned down and with a vertical rib along the middle. This rib cut away for the rails, which are fastened by bolted clips. General section thus, ╱‾‾ ‾‾╲. See No. 334,228. (Manufactured by the International Railway Tie Co., of New York. See Appendix B of report on metal track.)

No. 312,881; date, February 24, 1885; W. McVey.—A metal cross-tie in two pieces, mortised together at the middle and secured by a bolt.

No. 313,072; date, March 3, 1885; A. A. Harrison.—A combined flat longitudinal and cross tie; the cross-tie having plate at right angles and being laid so that these plates of adjacent ties meet.

No. 314,757; date, March 31, 1885; C. H. Van Orden.—A cross-tie of T section, with a rail chair at each end, the rails being secured by bolts which have hooked ends passing through the top of the tie.

No. 315,047; date, April 7, 1885; M. A. Martindale.—Longitudinals of inverted-trough section with rails forming a part of or bolted to the top table. Connected by transverse tie plates. Claimed to be adapted for laying along highways.

No. 315,771; date, April 14, 1885; L. Haas.—A cross-tie made of two pieces the full length of the tie, with the section of figure 1, having wooden-bearing blocks to which the rails are spiked. See No. 257,752.

No. 317,244; date, May 5, 1885; H. Thielsen.—A cross-tie of T section, the sides of the top table being turned down. (See No. 242,850.)

No. 317,763; date, May 12, 1885; M. A. Glynn (of Cuba).—Cross-ties of _∩_ or ⊥ section; also longitudinals of inverted trough section.

No. 319,010; date, June 2, 1885; A. J. Moxham.—A cross-tie made of two angle-irons, with distance-plates at the ends and middle ┌─ ─┐; the rails are bolted to high chairs. The tie is intended for street railways, and is shown with a center-bearing girder-rail.

No. 319,813; date, June 9, 1885; G. C. H. Hasskarl.—A hollow box cross-tie, with a ‾Y‾-shaped web inside; the small middle space receiving the T heads of the track-bolts. It is also to be used as a longitudinal sleeper for street railways, the two large side spaces being used as conduits for telegraph wires, etc.

No. 320,231; date, June 16, 1885; E. D. Dougherty and George B. Bryant.—A cross-tie of rectangular section, with an opening in the top table to receive a smaller cross-tie to which the rails are fastened, and which rests on springs placed in the larger box.

No. 323,356; date, July 28, 1885; G. Murray.—A flat cross-tie thickened under the rail, and having a rib at the bottom under each rail, and in the middle; the rails secured by bolted plates.

No. 323,430; date, August 4, 1885; J. K. Lake.—A combined metal stringer and chair for street railways.

No. 323,809; date, August 4, 1885; William B. Henning.—A longitudinal plate lies under each rail; with cross-ties having deep ends with ⊥ slots to receive the web and flange of the rails. (See 376,884.)

No. 325,020; date, August 25, 1885; R. R. Shepard.—A cross-tie of channel section ⊓ with one outer and one inner lug for each rail, and two ┌ slots for clips of ⊏-shape with eccentric heads.

No. 326,874; date, September 22, 1885; P. Kirk (of England).—A cross-tie with increased thickness at the rail seats, and with two lugs or clips punched up to hold the flange of each rail; the rail being secured by a wedge driven between the flange and one of the lugs (patented in England, France, Belgium, and Spain, in 1885).

No. 327,285; date, September 29, 1885; J. Lockhart.—An improvement upon No. 299,557.

Nos. 327,745 and 327,843; date, October 6, 1885; L. E. Whipple.—A cross-tie of X section, made of two curved plates placed back to back and having flat plate across top and bottom.

No. 328,632; date, October 20, 1885; J. S. Ammon.—A cross-tie of Λ section with rail chairs secured to the top ridge.

No. 329,429; date, November 3, 1885; G. E. Baldwin.—A pair of rail chairs of _∩_ shape, resting on wooden blocks and tied together by a rod. The top table has a groove to receive the web of a rail of T section, having no bottom flange. Intended especially for city railways.

No. 329,821; date, November 3, 1885; P. Davey.—A cross-tie of channel section, to which the rails are secured by keys and Z-shaped clamps, the lower part of the latter lying inside the tie.

No. 332,384; date, December 15, 1885; J. Conley.—A fastening for attaching rails to metal ties, which have lugs to hold the outer flange of rail. The fastening is a bar inside the tie, with a hook at one end projecting through a hole and holding the rail flange, while the other end is bent up against the end of the tie. (See 254,802.)

No. 333,015; date, December 22, 1885; J. Howard and E. T. Bousfield (of England).—A cross tie of ⌒ section, with a U-shaped depression for each rail, the rail being secured with a wooden wedge. (These ties have been used with the English double-headed rail; patented in England.) (See 335,523.)

No. 333,480; date, December 29, 1885; L. B. Prindle.—A steel cross-tie three-eighths to one inch thick; channel section ⊓; at each end is a slot to receive a tenon at the bottom of a rail chair.

No. 334,228; date, January 12, 1886; E. N. Higley.—An improvement on No. 312,717. (See 353,028.)

No. 334,696; date, January 19, 1886; H. L. De Zeng.—An improvement in fastenings. (See Nos. 145,991 and 155,369; also 380,623.)

No. 335,523; date, February 2, 1886; J. Howard and E. T. Bousfield (of England).—A cross-tie made of a metal sheet or plate, with one or more corrugations lengthwise, the rails being held in chairs made by cutting away the corrugations. (See No. 333,015.)

Nos. 335,804 and 335,805; date, February 9, 1886; E. P. J. Freeman.—A cross-tie made of a sheet of metal bent to form a rectangular box. A wooden block is placed inside, under each rail, and a spike is driven into the wood through a hole in the metal. The spike may be split so as to flare like Λ when driven in combination, a guard-rail of a plate bent to Z shape, the rail lying on the bottom flange and all fastened to the tie.

No. 338,057; date, March 16, 1886; J. Gearon.—A continuous road-bed made of channel cross-ties placed alternately ┌─┐ and └─┘, with the vertical flanges overlapping one another.

No. 339,275; date, April 6, 1886; J. DeMott.—A cross-tie with a rail chair at each end. The end of the tie is rounded on plan, and is embraced by a ⊂ clamp with the ends turned up to hold the rail flange.

No. 339,938; date, April 13, 1886; F. F. Scott.—A cross-tie with a chair for each rail; one half of chair fixed, the other fastened by bolts. Pins driven through the web of the rail prevent vertical movement.

No. 340,118; date, April 20, 1886; H. Howard.—A deep channel └─┘ cross-tie for street railways. The rails are keyed to chairs resting on the top of the flanges.

No. 341,416; date, May 4, 1886; F. V. Greene.—For street railways. A continuous cast-iron hollow bearing (preferably 10 feet long and weighing 140 pounds per yard) under each rail. The rails are grooved, and are screwed to the top of the longitudinal.

No. 342,987; date, June 1, 1886; A. N. Warner and T. J. Deakin.—A cross-tie of channel section └─┘ with T-shaped rail chairs fitting into it. The rail secured to chairs by bolts with hooked ends, the nuts being under the flange of the chair.

No. 344,011; date, June 22, 1886; C. H. Sayre.—Flat or arched ⌒ cross-ties with pieces punched out of the top and bent to embrace the flange and web of the rail.

No. 344,185; date, June 22, 1886; W. Kilpatrick.—A cross-tie of ◡ section, with a slot along the flat top to receive the bottom of the rail chairs.

No. 344,826; date, July 6, 1886; I. F. Good.—A flat cross-tie thickened and widened at the ends to form rail chairs, and having flanges projecting down under the chairs. The rails secured by keys.

No. 345,733; date, July 20, 1886; C. Sailliez.—A cross-tie of channel section ┌─┐, with lugs to hold the rail flanges. The flanges are cut away at the ends to allow of wooden stringers being used under the rails.

No. 346,998; date, August 10, 1886; D. Kaufman.—Flat cross-ties with chairs at the ends, and longitudinal continuous flat plates beyond the chairs. The space between the rails is covered by a continuous arched plate.

No. 349,524; date, September 21, 1886; E. Schmidt (of Prussia).—A cross-tie made of two old flange rails laid flat, head to head, forming a tie of H H section. The rails rest on the web and are fastened by bolted clips. (Patented in Germany.)

No. 350,692; date, October 12, 1886; T. L. Mumford and H. Moore.—A cross-tie of inverted trough section, wider at the ends, with fixed lugs and movable clamps for fastening the rails.

Nos. 351,498 and 351,499; date, October 26, 1886; E. C. Davis.—A cross-tie made of two old rails placed side by side. Each track rail rests on a bearing-block in two pieces, with a lip at the end to engage the rail flange. The blocks are slid into place between the tie-rails and bolted through the tie.

No. 352,002; date, November 2, 1886; E. F. Reynolds.—A cross-tie of IΛΛΛI section. The rails rest in notches cut in the top, and are held by hinged clips and locking clips.

No. 353,028; date, November 23, 1886; E. N. Higley.—Improvements upon Nos. 334,228 and 312,717.

No. 353,691; date, December 7, 1886; S. D. Locke.—A channel cross-tie ┌─┐, with inclined ends and a transverse rib in the middle. The rails are fastened by bolted clips. (See 356,002.)

No. 354,250; date, December 14, 1886; R. S. Sea.—A cross-tie of T section with enlarged ends forming rail chairs. (See 379,005.)

No. 354,433; date, December 14, 1886; R. Morrell.—A cross-tie made of a plate bent to form a hollow rectangular box, with the top and bottom cut away at the middle. The rails are fastened to wooden bearing-blocks placed inside the tie. (See 365, 932.)

No. 356,002; date, January 11, 1887; S. D. Locke.—An improvement on No. 353,691.

No. 358,144; date, February 22, 1887; J. Clark.—A cross-tie of channel section, with chairs for the rails. (See No. 249,503, etc.)

No. 358,981; date, March 8, 1887; J. C. Lane.—An iron bridle-rod, made in two pieces, bolted together at the middle, to prevent rails from spreading at the curves.

No. 359,115 and No. 359,117; date, March 8, 1887; W. Wharton, jr.—A cross-tie of ⊥ or L section, with the bottom flange bent up to make a chair for the rails. To be used on street railways with girder rails.

No. 359,440; date, March 15, 1887; T. Gleason.—A cross-tie of trough section ⊔, with interior cross-pieces or webs to which the rail clamps are fastened.

No. 360,397; date, March 29, 1887; M. Y. Thompson.—A flat cross-tie, with a U shaped depression at each end to receive a wooden bearing-block. The rails are fastened by keys.

No. 361,199; date, April 12, 1887; H. P. Adams.—A cross-tie of T section, with chairs keyed to it.

No. 361,330; date, April 19, 1887; P. J. Severac, of Paris.—A cross-tie of I section, with the horizontal flanges bent at the ends. In some cases a broad plate is riveted to the bottom flange. The rails are fastened by clips or keyed to chairs. (This system is in use in Europe.) Patented in France, Belgium, England, Italy, and Spain, in 1884–'85.

Nos. 362,786 and 362,787; date, May 10, 1887; J. Riley (of Scotland).—A cross-tie of inverted trough section, with the rail chairs stamped or pressed by dies, the rails being secured by wedges. (Patented in England and Belgium; 1885–'86).

No. 363,020; date, May 17, 1887; L. Taylor.—A hollow box cross-tie, with outward-flaring sides and concave bottom. The rails are fastened by hook bolts with the nuts inside the tie.

No. 364,350; date, June 21, 1887; A. Roelofs.—A cross-tie of channel ⊓ or inverted trough section. The rails are fastened by fixed lugs on the outside, and a tie-bar which is sprung into place on the inside. Also a flat tie with a rib under each rail and a slot along the middle for the bent tie-bar.

No. 365,511; date, June 28, 1887; F. X. Georget.—A cross-tie or longitudinal, of channel section ⊔, built up of a base plate and two concave side plates with the tops flanged outward horizontally. The ties or longitudinals are connected by tie rods. (See 381,125.)

Nos. 365,932 and 365,933; date, July 5, 1887; R. Morrell.—A hollow cross-tie, made of a plate bent to an oblong section, with straps around it at the rail fastenings. The metal is cut away to let the rails rest on a wood block inside the tie; the metal straps keep the spikes from working loose and allowing the rails to spread. Also a tie for elevated roads, made of two plates on edge, fastened together at the middle, and flaring apart to admit wooden bearing-blocks between them. See No. 354,433.

No. 366,546; date, July 12, 1887; N. S. White.—A cross-tie of channel ⊓ or inverted trough section, with a base plate at each end, with a bearing-block of wood or other material inside under each rail. The rails are fastened by locking clamps.

No. 367,325; date, July 26, 1887; John Splane.—A cross-tie of ⊓ channel section, with the bottom of the sides flanged outwards. The rails are let into apertures in the top and rest on the hooked ends of two tie-bolts, the inner ends of which are connected by a turnbuckle which is tightened by a wrench, there being a hole in the middle of the top table of the tie.

No. 367,383; date, August 2, 1887; J. Fitzgerald.—The rails are fastened to a cast-iron cross-tie by hook-headed spikes, which are secured by horizontal keys fitting into corresponding notches in the tie and spike.

No. 369,591; date, September 6, 1887; J. H. Coffman.—A solid tie with a groove along the top and lugs for the inner flanges of the rail; hooked rods hold the outer flange, and the inner ends of the rods are attached to a spring at the middle of the tie.

Nos. 369,755 and 369,756; date, September 13, 1887; William L. Van Harlingen, sr.—A box cross-tie made of an inverted trough fastened to a base plate; inclined and closed ends. It incloses a wooden tie or wooden bearing blocks. The rail is fastened by wood-screws with wide heads. Also a metal tie with end boxes to contain springs on which the rails rest.

No. 370,072; date, September 20, 1887; R. C. Lukens.—A cross-tie of **T** section, with slots in the web for attaching weights or anchors to keep the track in position. The rails are fastened by lugs and bolts.

No. 370,192; date, September 20, 1887; D. C. Heller.—A hollow box-tie of rectangular section, with the top cut away under the rails. The tie is filled with concrete and has two wooden blocks to which the rails are spiked.

No. 370,226; date, September 20, 1887; C. W. Yost.—A flat tie with lugs, and a separate bed-plate, with lugs, for each rail.

No. 370,634; date, September 27, 1887; J. Mahoney and D. W. Shockley.—A cross-tie of ⊥⊥ section, with a saddle plate for each rail seat. The plate has a lug for one flange and a clip is bolted on the other. See No. 280,200.

No. 371,110; date, October 4, 1887; W. H. Troxell.—A cross-tie with raised rail seat and outer lugs. Hooked bolts, with nuts on the outer side of the chair, hold the inner flange of the rail.

No. 371,780; October 18, 1887; J. Moser and E. Moeckel.—A cross-tie of **T** section, with a chair at each end; each chair has an inclined rail-brace and two hook-bolts.

No. 372,230; date, October 25, 1887; A. McKenney.—Cross-ties of channel ⊓ section, with one end cut off at an angle to allow of a diagonal tie to the next transverse tie, each set of three ties making a letter **N** on plan. Arranged continuously.

No. 372,525; November 1, 1887; J. A. Dunning.—A hollow rectangular cross-tie, with open inclined ends; bottom and sides have corrugations, transverely and vertically. Bolted clip fastenings.

No. 372,703; date, November 8, 1887; I. A. Perry.—A cross-tie made of two old rails, with saddle chairs fitting over the heads of these rails. Track rails fastened by chair and sliding wedge, being held by flange and web.

No. 372,864; date, November 8, 1887; C. Netter.—A cross-tie of **T** section, with the ends beyond the rails bent down vertically and then horizontally. Rails fastened by bolts having hooks, which take hold of the bottom of the web of the tie.

No. 372,879; date, November 8, 1887; J. H. Stull.—A cross-tie made of a plate bent to a semi-circular form ◡, and semi-cylindrical at the ends ⊍. Rails fastened by clamps. Open ends.

No. 373, 656; date, November 22, 1887; W. P. Hall and C. C. Barnett.—A cross-tie of semi-circular section ◠, with open ends. Shoulders pressed out to prevent spreading. Rails fastened to saddles or straps. (See 375,996.)

No. 375,005; date, December 20, 1887; R. S. Sea.—A cross-tie of channel section, with closed ends. A strengthening plate is bolted to the under side of the top table, and the side flanges are deeply notched to give elasticity. A metal block is bolted under each rail, and the rails are secured by bolted plates.

No. 375,856; date, January 3, 1888; R. T. White.—A cross-tie of ⊥ section, with high chair at each end to receive the web of a girder rail. Intended for street railways. (See 385,395.)

No. 375,996; date, January 3, 1888; W. P. Hall.—A hollow cross-tie, made of a plate bent almost cylindrical, but with the bottom open and flat on top. The rails are fastened to saddle straps. (See 373,656.)

No. 376,214; date, January 10, 1888; J. W. Smith.—A hollow rectangular cross-tie, with holes in the top to admit the rail chairs, which rest on coiled springs inside the tie.

No. 376,884; date, January 24, 1888; William B. Henning.—A flat bar, bent up at the ends to embrace the flange and web of rail. Loose angle clamps on inside of rail. (See 323,809.)

No. 377,162; date, January 31, 1888; G. Kelton.—A cross-tie of channel section ⊓, with a separate bottom, having projections on its inner side to give a hold to the pulp with which the tie is to be filled. The rails are fastened by hooked bolts, with nuts inside the tie, cavities being left in the pulp filling.

No. 378,280; date, February 21, 1888; F. L. Barrows.—A cross-tie of inverted trough section, with clips struck up on the outside of the rail to hold its flange, and clips lengthwise on the inside of the rail to hold a rail fastening.

No. 378,930; date, March 6, 1888; J. Hill.—A flat cross-tie, corrugated lengthwise top and bottom. The rail is keyed to a chair. The inventor proposes to use a double-headed rail.

No. 379,312; date, March 13, 1888; S. B. Jerome.—A hollow rectangular cross-tie, made of a bent plate. It is to be filled with straw, sawdust, etc., and has a narrow bearing-block along the underside of the top, to which the rails are spiked. The ends are closed by wood or cement blocks.

No. 379,399; date, March 13, 1888; J. Jacobs.—A cross-tie of channel section ⊔ with closed ends; a top plate is bolted on by side clamps to form a rail seat. The tie is to be filled with concrete, etc.

No. 379,574; date, March 20, 1888; C. P. Hawley.—A cross-tie of I section, with the top flange bent to make a rail brace. A longitudinal bridge is used under the rail at joints.

No. 379,576; date, March 20, 1888; C. P. Hawley.—A cross-tie of ⊥ section, with slots for the web of a T girder, forming a rail seat, or which can be made a longitudinal bearing.

No. 380,623; date, April 3, 1888; H. L. De Zeng.—Improvements upon Nos. 334,696 and 348,550.

No. 381,125; date, April 17, 1888; F. X. Georget.—Improvements upon No. 365,511.

No. 381,860; date, April 24, 1888; E. R. Stiles.—A cross-tie of channel section ⊔, with a wooden block under each rail.

No. 382,134; date, May 8, 1888; W. H. Britton.—A cross-tie of T section, with the vertical web corrugated vertically. The rails are secured by lugs and clamps.

No. 382,394; date, May 1, 1888; J. B. Sutherland.—A cross-tie of approximately Y section; curved like the section of a yacht, and with the top edges bent in to form horizontal flanges for the rail chairs.

No. 382,855; date, May 15, 1888; F. Barhydt.—A hollow box cross-tie, with closed ends. There is a wooden block the full size of the face of the tie at the top, and another at the bottom; both inside. Coil springs are interposed between the top and bottom sections.

No. 383,118; date, May 22, 1888; M. Fitzgerald.—A cross-tie of channel section ⊓, with solid ends. Fixed lugs and hooked spikes are the rail fastenings.

No. 384,785; date, June 19, 1888; Jacob Reese.—A cross-tie of ∩ section, with a groove along its top table; rail seat bolted on top. The rail is secured by a bolt passing under it and through the chair, having ┌ washers to hold the rail flange. It is to be rolled from a plate of No. 7 steel 24 inches wide; bedded in ballast.

No. 385,395; date, July 3, 1888; R. T. White.—A channel cross-tie of U section, with rails secured to saddles by bolts and clips. (See 375,856 and 386,420.)

No. 385,492; date, July 3, 1888; D. Y. Wilson.—A cross-tie made of two angles ┘ └, with a base plate and channel plate for rail seat at each end. Rails bolted through top and bottom plates.

No. 386,119; date, July 17, 1883; R. W. Flower, jr., and S. L. Wiegand.—A hollow cross-tie of rectangular section, with part of the bottom cut away and turned down to prevent lateral movement. The rails are spiked to wood blocks inside the tie.

No. 386,156; date, July 17, 1888; J. A. Ogden.—A cross-tie of channel section ⊔, wide at the bottom, with bearing blocks and hook-fastenings for the rails.

Nos. 386,356 and 386,357; date, July 17, 1888; H. Shultzen.—A channel tie ⊔, with the middle part of the bottom cut away and turned up to prevent lateral movement. The rail is fastened to a wooden block by **Z**-clips and a longitudinal bolt under the rail, or by diagonal bolts. (Now being manufactured by the Standard Steel Tie Company, of New York.) (See Appendix B of the report on metal track.)

No. 386,389; date, July 17, 1888; A. Durand.—A cross-tie of inverted trough section, with clips and channels stamped in it. (See description on p. 25.)

No. 386,420; date, July 17, 1888; R. T. White.—Hollow box cross-ties of different sections, made of bent plates. Cross-section intended to give elasticity. (See 385,395.)

No. 388,277; date, August 21, 1888; A. J. Hartford.—A flat cross-tie, with end turned up, and a bent plate tie bridge, arched in the middle, bent to form a shoulder for inner flange of rail; the rail rests on this plate and the end is turned over the outer flange and secured by a bolt through both plates.

No. 389,464; date, September 11, 1888; L. Haas.—A cross-tie of rectangular section; top cut away at ends and middle. Wooden block under each rail. (See 391,704.)

No. 390,014; date, September 25, 1888; R. P. Faddis.—Wooden stringers, with flat iron tie plates across top and under rail, with **U** bolts embracing the stringers. For street and steam railways.

No. 390,370; date, October 2, 1888; I. G. Howell.—A cross-tie of channel section ⊓, with blocks under the rails. The top is cut away for the rail, and the rail clamps are fastened by hooks.

No. 391,492; date, October 23, 1888; W. J. Stifler.—A flat cross-tie with diagonal grooves on the under side near the ends to receive the heads of the bolts of the two plates, each with a lug, which form one rail seat.

No. 391,704; date, October 23, 1888; L. Haas.—A cross-tie of channel section ⊔, higher at the rail seats, with notched flanges for the rails. (See 257,752.)

No. 391,999; date, October 30, 1888; A. H. Ames.—A flat cross-tie, with flaring ends of channel section ⊓, having riveted and bolted clips for rail fastenings.

No. 392,849; November 13, 1888; J. Cabry and W. H. Kinch (of England).—A rolled steel cross-tie of inverted trough section, with lugs stamped out. Rails secured by keys driven between flange and lug. (In use on the Northeastern Railway, in England.)

No. 393,515; date, November 27, 1888; D. M. McRae.—A wooden or iron tie, with metal sockets at ends forming rail seats.

No. 394,738; date, December 18, 1888; G. W. Thompson.—A hollow cross-tie of rectangular section, with a metal bearing-block inside under each rail. Bolted clip rail fastenings.

No. 395,134; date, December 25, 1888; M. Hagarty.—A cross-tie made of two channels placed back to back ⊐⊏, inner lug on one, outer lug on the other. The bolt holes in vertical web are elongated to allow the channels to be shifted to let rail in.

No. 395,304; date, December 25, 1888; C. F. Yarbrough.—Hollow cross-ties of rectangular section, with open ends and openings at sides. Wood blocks may be used, or the ties may be filled with ballast.

No. 396,160; date, January 15, 1889; H. Hipkins (of England).—A stamped metal cross-tie of ⌒ section, with lugs and rib stamped out of top table. (Patented in England, 1888.)

No. 396,473; date, January 22, 1889; C. P. Espinasse (of France).—A cross-tie of ⊥ section, with vertical web cut away for rail chair to which rail is secured by wooden wedge.

No. 398,004; date, February 19, 1889; S. U. Smith.—A cross-tie of channel section ⊓, with closed ends. The rails rest on the ends of a separate cross-plate, with fixed lugs inside, and bolted plates outside.

TREATMENT OF RAILWAY TIES IN ENGLAND.

The information given below is taken from a paper on "English Railroad Track," by Mr. E. E. Russell Tratman (Transactions of the American Society of Civil Engineers, June, 1888). The matter referring to the Great Northern Railway (of Ireland) was taken by Mr. Tratman from a highly interesting paper, "Description of a Creosoting Yard for Railway Purposes," by Mr. W. Greenhill, read before the Institution of Civil Engineers of Ireland, in May, 1886; the paper contains very full particulars, in detail, of the plant and process, results of tests, cost, etc., and is especially interesting in that it describes work done by a railway company in treating timber for its own use.

The ties are usually of Baltic red wood, 10 by 5 inches by 9 feet, spaced 2 feet 9 inches to 3 feet center to center. They are almost invariably creosoted, with about 7 pounds of oil per cubic foot. Some roads have the creosoting done by contract, others have their own plant for the work. Among the latter may be mentioned the Lancashire and Yorkshire Railway and the Great Northern Railway (Ireland), both of which have very large and complete plants, and pay careful attention to the important point of tie preserving. [See also paper by Mr. John Bogart, M. Am. Soc. C. E., entitled "The Permanent Way of Railways in Great Britain and Ireland; with Special Reference to the Use of Timber Preserved and Unpreserved," and read November 20, 1878.*] I do not think enough practical attention is paid in this country to the question of preserving railroad ties, and some points in the matter may be learned from English practice.

Usually the ties are of rectangular section, but on the Midland Great Western Railway (Ireland), they are preferred of half-round section, except where the bearing-plates (bed plates) are used. Mr. Price says that for heavy traffic he would prefer sleepers 11 by 5½ inches; he uses, however, sleepers 10 by 5 inches, 8 feet 11 inches long, always creosoted. The following is from the company's specifications: The timber is to be of good sound Baltic redwood, free from shakes and other defects, well seasoned and dry; 90 per cent. of both rectangular and half-round sleepers to have not less than 7½ inches diameter of heart-wood, and 10 per cent. not less than 7 inches at both ends. On one side the rectangular sleepers to have 50 per cent. sharp edges down to 9 inches surface, and 50 per cent. not less than 8 inches, and on the other side all edges to be sharp. The rectangular sleepers are to be grooved and bored and the half-round sleepers to be grooved, in accordance with the templates which will be supplied by the engineer. After being grooved and bored they are to be placed in a receiver and thoroughly impregnated with the best creosote oil (an equal mixture of light brown and black oil) under such pressure and for such time as shall entirely fill the pores with the liquid. The sleepers are not to be creosoted till they have been stacked in the contractor's premises for at least three months after inspection by the engineer.

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* Transactions, Vol. VIII, page 17, January, 1879.

The engineer will reject, either before or after delivery, any sleepers which do not comply with the above conditions, or any sleepers the sap-wood of which has not been fully creosoted.

(1) LANCASHIRE AND YORKSHIRE RAILWAY.

The ties, after being well seasoned, are passed through a combined adzing and boring machine, which first cuts out a seat about one-sixteenth of an inch deep for the chairs, in order to give them a uniform bearing, and then simultaneously bores the eight holes required for chair fastenings in each tie. The machine will seat and bore about one hundred ties per hour.

The ties are then placed on small iron trucks and drawn on a tramway of 3-foot gauge into the cylinder, which contains eight trucks with forty-seven ties each, or three hundred and seventy-six ties in all. The cylinder is 77 feet long, 6 feet internal diameter, built of one-half-inch wrought-iron plates and having egg-shaped ends. When the full number of ties has been put in, the doors or covers are put on and hermetically fastened by means of dog-bolts and screws, and the air exhausted by a steam ejector. The creosote is then introduced, heated to a temperature of from 100 to 120 degrees Fahrenheit; the air-pump then ceases to work and the pressure pump is put into operation, the full pressure of 150 pounds per square inch being obtained in about ten minutes; this pressure is maintained for about fifty minutes and is then withdrawn. The spare creosote is allowed to run back into the reservoir under the cylinder, the cover is removed, and after the ties have been left to drip for about fifty minutes, they are taken out of the cylinder. About 3 gallons of creosote are allowed for each tie, or 9½ pounds per cubic foot of timber. The efficiency of the process is ascertained by weighing three or four ties out of every charge, both before and after the operation, the additional weight showing the quantity absorbed, which averages about 30 pounds per tie:

	Pounds.
Average weight of tie before creosoting	128
Gain in weight during process	30
Average weight of creosoted tie	158

The whole operation for one charge of ties occupies about one hundred and thirty-two minutes, as follows, but varies slightly, however, according to the moisture in the timber:

	Minutes.
Ejection vacuum	13
Pumping commenced and tank filled	9
Full pressure obtained in	10
Full pressure maintained for	50
Spare creosote allowed to drip from ties	50
Total	132

From the creosoting cylinder the timbers are run back into the chairing shed, where the chairs are attached to the ties by a machine (somewhat on the style of a steam hammer) which, at one stroke, drives the four fastenings for each chair. This machine will "chair" about seventy ties per hour.

The time occupied in seating, boring, creosoting, and chairing three hundred and seventy-six ties is as follows:

	Hrs.	Min.
Seating and boring	3	40
Running trucks into cylinder	0	20
Creosoting	2	12
Withdrawing charge from cylinder	0	20
Chairing	5	14
Total	11	46

or 1 minute and 53 seconds per tie.

The cost of the operations, not including the value of the machines, is as follows:

Loading white ties	per 100	$0.36
Adzing and boring	do	.62
Tanking,	do	.64
Creosote, 300 gallons	do	6.75
Chairing and spiking	do	2.44
Total		10.81

or 10.81 cents per tie.

The whole of the work is done at the company's store yards at Castleton and Knottingley, and is let piece-work at the above rates.

(2) GREAT NORTHERN RAILWAY (IRELAND).

In 1876, when a number of railways were amalgamated to form this system, the new company decided that all the ties should be creosoted, and that to insure the work being efficiently performed, it would erect a suitable plant of its own for sawing, grooving, and creosoting the timber to be used for ties. After being sawed, the ties are taken to the grooving-machine, which forms a groove or seat for the base of flange rails by means of cutters making 2,000 revolutions per minute. Boring machinery, with twisted augers, was used for a short time, but the adoption of the improved ragged spike, which cuts its own way without splitting the tie, enables holes to be entirely dispensed with, and insures a tighter fit of the spike. After being grooved the ties are run out into the yard on a tramway of 30-inch gauge, and stacked to a height of 14 feet, alternate tiers on edge and on flat.

The cylinder is 60 feet long (6 tie lengths), 6 feet diameter, built of three-eighths-inch plates. The safety valve is set at 110 pounds, but seldom rises; it is, however, sometimes lifted to release air and water when the pressure pumps are working. There are six tanks, of such a size that a vertical inch of the six tanks represents 156 gallons; a float is connected with a gauge and scales, which show the gallons or pounds of creosote forced into the cylinder. There are 1½-inch pipes in the cylinder, through which the steam is forced to heat the creosote to 120 degrees Fahrenheit, thus dissolving the naphthaline, etc., and rendering the creosote quite fluid. There is an air-pump, 6¼ by 10 inches, which exhausts the air from the cylinder, and the creosote enters by the atmospheric pressure on the tanks; the partial vacuum does not extract the sap or affect the timber. When the cylinder is nearly full the valve is closed, air-pump stopped, and the two force pumps, 3 by 4 inches, put to work. Three hours of steady pressure are required. The consumption of oil varies from 140 to 180 casks of 36 to 38 gallons each, per week, and the quantity used annually is about 250,000 gallons. The average quantity of creosote injected is 2.35 to 2.57 gallons, or 25 to 27 pounds per tie. About nine months' seasoning is customary, but a longer period is considered desirable so as to insure dryness.

"Little or no creosote can be forced into a thoroughly wet sleeper, even at high pressures, and a thoroughly dry sleeper will readily absorb a large quantity of oil which, when solidified by exposure to the air, no moisture, either from air or wet ground, will succeed in removing."

CIRCULAR IN REGARD TO CHESTNUT-OAK TIES.

FOR INFORMATION OF RAILROAD MANAGERS.

U. S. Department of Agriculture, Forestry Division,
Washington, D. C., December, 1887.

Gentlemen: Hoping that you have appreciated the manner in which the Forestry Division of this Department has, by its first Bulletin, attempted to call the attention of railroad managers to the need of economy in the use of forest supplies, allow me, in furtherance of such economy, to present the following statements, which may be of interest to you.

In the use of oak for cross-ties, the specifications of most roads, especially those of the South, call for white oak (*Quercus alba*), a timber which is sought for also by almost every industry employing oak, and which is therefore rapidly decreasing and approaching comparative exhaustion. Meanwhile, millions of feet of tan-bark or chestnut oak (*Quercus prinus*) are rotting in the forests, after being stripped of their bark, because their value for cross-ties is not known or is underestimated in many regions.

This lack of appreciation of the value of this wood causes not only waste of the wood itself, but waste of the bark also, as without ready demand for the wood it does not pay to peel the larger limbs.

From information furnished by Dr. Mohr, of Mobile, Ala., an expert in forestry statistics and agent of this Department, it appears that from the line of the Louisville and Nashville Railroad, south of the Tennessee River, between 5,000 and 7,000 cords of bark are shipped annually, involving the felling in that district alone of from 10,000 to 13,000 trees which are consigned to useless destruction, while capable of yielding not less than 100,000 first-class railroad ties.

As to the lasting quality of the timber of chestnut oak, experiences are reported from Cullman, Ala., to the effect that posts of this oak outlast those made of white oak, partly, probably, because the timber is peeled. One reliable report states that tan-bark-oak posts were found to be sound after twelve years, while those of white oak in the same construction had to be replaced several years sooner. Reports from railroad companies where this wood is used for ties give their life as from five to ten years, while the reports for white oak give from three to twelve years. In the average, all the oaks which are known as "white oaks," named below, last between seven and eight years in the road-bed.

That the oaks of this class may be used for railroad construction interchangeably, and do not offer any appreciable differences in the qualities most essential for a good railroad tie, the following table, compiled from the Census Report, may serve to show. The column of specific gravity will allow an estimate in regard to adhesion of spikes, while the column of indentation allows an estimate as to resistance to cutting of rail.

The position as to quality, in comparison with the other kinds mentioned, is indicated by numbers in parentheses.

Description.	Range.	Weight per cubic foot.	Specific gravity.	Resistance to indentation.	Elasticity.	Transverse strength.
White oak (*Quercus alba, L.*).	East of the Rocky Mountains.	46.35	0.7470 (4)	3388 (6)	97089 (2)	905 (4)
Chestnut or rock-chestnut oak (*Quercus prinus, L.*).	Northeastern and in Kentucky, Tennessee, and Alabama.	46.73	0.7490 (3)	3688 (5)	125473 (1)	1031 (2)
Basket or cow oak (*Quercus Michauxii, Nutt.*).	Southeastern	50.10	0.8039 (2)	3725 (4)	96373 (3)	1118 (1)
Burr, mossy-cup, or over-cup oak (*Quercus macrocarpa, Michx.*).	Northern United States.	46.45	0.7453 (6)	3730 (3)	92929 (4)	982 (3)
Post or iron oak (*Quercus obtusiloba, Michx.*).	East of Rocky Mountains.	52.14	0.8367 (1)	4415 (1)	83257 (5)	872 (6)
California white oak (*Quercus Garryana, Dougl.*).	Pacific Coast	46.45	0.7453 (5)	3846 (2)	81109 (6)	879 (5)

From these figures it would seem that, contrary to the accepted notion, the white oak, par excellence, is inferior in all particulars to the chestnut oak, and in general not superior to any of the others.

Trusting that the above information will be of value to you, and that, so far as your conditions enable you to make use of it, you will do so, and thus to some extent aid in economizing timber supplies.

Yours, respectfully,

NORMAN J. COLMAN,
Commissioner of Agriculture.

NOTE.—The objection to the injurious influence on their durability of cutting trees in the sap, which is done to obtain bark, is met by leaving the trees full length, with limbs and leaves untrimmed for a fortnight, when by the action of the leaves a more thorough seasoning will be accomplished than can otherwise be obtained.

This practice is common abroad wherever summer felling is a necessity, and has proved itself so satisfactory that preference is given to cutting timber in the leaf.

CORRESPONDENCE IN REPLY TO THE CIRCULAR ON CHESTNUT-OAK TIES.

Louisville, New Orleans and Texas Railway Company.—My own experience confirms fully the facts stated in your circular. (James M. Edwards, vice-president and general manager.)

Richmond and Allegheny Railroad.—I have ranked chestnut oak with white and post oak for thirty years past, and in the middle sections of the State the impression is that, cut under similar conditions, it rather outlasts the white oak. (R. D. Whitcomb, chief engineer.)

Cincinnati, New Orleans and Texas Pacific Railway Company.—I have seen your circular concerning the value of chestnut oak, and am glad that you called attention to the subject.

We have had its use specified for our cross-ties on the Cincinnati Southern Railway since the first construction of the track, in 1876. (G. B. Nicholson, chief engineer.)

Nashville, Chattanooga and Saint Louis Railway.—Please accept my thanks for your circular letter with reference to chestnut oak for cross-ties. Our chief engineer advises me that he classes it third best for this purpose, and considers it but little inferior to white oak for cross-ties. (J. W. Thomas, president.)

Saint Louis and San Francisco Railway Company.—Ninety-five per cent. of the timber fit for ties on our lines is composed of white, burr, or post oak. We have occasionally obtained a few ties made of what is called chinquapin oak, which is a variety of chestnut oak, and has long been recognized to be one of the best varieties of timber for cross-ties. (James Dun, chief engineer.)

Philadelphia, Wilmington and Baltimore Railroad Company.—We have bought several thousand of *Quercus prinus* in the Virginia counties bordering on the Chesapeake Bay this last season. I consider it every way equal, if not superior, to the *Quercus alba* ties. If you can direct me where the bark of the *Prinus* is being used, I will at once send our agent to see what we can do towards getting the cross-tie in the spring after the trees are barked. (J. N. Mills, superintendent.)

Mexican Central Railway Company.—We are using on our railroad now, so far as we draw from the United States, for the main line, cedar grown in northern Michigan and southern Canada, and we have already contracted for 1,000,000 ties for next year's supply.

We have also bought 25,000 white-oak ties. These are the only oak ties that have been purchased in the three and a half years of my presidency, with the exception of some small lots of bridge ties. So, as you see, we have not been very great sinners in the matter of the use of white oak.

The 25,000 oak ties were for use in curves; heretofore we have used on curves mesquite ties grown in Mexico; the supply was never plentiful, and it had materially diminished.

The information you give us, therefore, may become of great importance. (Levi C. Wade, president.)

SPECIFICATIONS FOR WOODEN CROSS-TIES.

PROPOSED GENERAL SPECIFICATIONS FOR CROSS-TIES.

TIMBER.

Cross-ties will be accepted of the following varieties of timber: Oaks of the various kinds known as "white," "black," "yellow," "rock," or "chestnut," "burr," and "post," red oak, black locust, second-growth white chestnut, beech, red elm, cherry, maple, butternut, tamarack, and yellow pine of the long-leaved Southern hard pine variety cut from untapped trees, white and red cedar. Hemlock may be accepted but only under special contracts.

SIZE.

First class. Eight and one-half feet in length, 7 inches in thickness, and not less than 7 inches width of face on both sides at the small end.

Second class. Eight feet in length, 6 inches in thickness, and not less than 7 inches width of face on both sides at the small end; and in each class there must be at east one-fourth of the whole number that will be not less than 10 inches in width of faces.

MANUFACTURE.

All ties must be made from sound, thrifty live or green timber, free from loose or rotten knots, worm-holes, dry-rot, wind-shakes, splits, or any other imperfections affecting the strength or durability of the timber.

Not more than 1 inch of "sap wood" will be allowed on the edges or corners, and none at all on either face of the ties; they must be hewed or sawed with the faces perfectly true and parallel, of the exact thickness specified; the faces must be out of "wind," smooth, and free from any inequalities of surface, deep score marks, or splinters; they must be cut or sawed square on the ends to the exact lengths given and be generally straight in all directions, and will not be accepted if more than 3 inches out of straight in any direction; and must be peeled or stripped entirely free from the bark before being delivered.

No "square ties," either hewed or sawed, will be accepted excepting under special contracts. No split ties will be accepted under any circumstances, and "culls" only at the option of the company, and at such prices as may be agreed upon from time to time.

DELIVERY.

All ties delivered along the line of the railway must be stacked up in neat square stacks of fifty ties in each, with alternate layers crossing each other, and on ground, wherever possible, as high or higher than the grade of the railroad, and in such position as to admit of being counted and inspected with ease and facility. Ties delivered at suitable and convenient places, acceptable to the company, will be inspected, and bills made for all received and accepted up to the last day of each month, and payment will be made for same on or about the —— day of the succeeding month.

—— ——,

Chief Engineer.

SPECIFICATIONS FOR CROSS-TIES USED BY NEW ORLEANS AND NORTHEASTERN RAILROAD.

The timber shall be either white, post, burr, or chestnut oak, mulberry, black locust, red cypress, or long leaf yellow pine, cut in any month of the year of delivery except February, March, April, May, or June, from young, sound, living trees. It must be free from rotten or loose knots, worm-holes, dry-rot, wind-shakes, or other imperfections affecting the strength and durability of the wood.

The cross-ties must be 9 feet long and straight in all directions, not less than 7 nor more than 7½ inches in thickness. They must have not less than 7 inches of heart face.

The hewn surfaces must be parallel, free from objectionable score-marks, and not winding. The ends must be cut square and all bark removed. No sawed ties will be accepted.

The ties must be delivered on the right of way of the railway, not lower than the grade, and not higher than 8 feet above grade.

They shall be scattered for inspection in such a manner that all parts of every tie can be seen and measured by the inspector.

All accepted ties must be arranged in piles formed of layers separated by two ties.

PROPOSAL.

The undersigned hereby propose to furnish, according to the foregoing specifications ——— cross-ties. Said cross-ties to be delivered as aforesaid at ——— ———, at the rate of —— cents per cross-tie.

The undersigned further propose to commence work within —— days from date hereof, and complete the delivery of ties on or before —— ———, 18—.

Signed this —— day of ———, 18—.

Name of firm : ——— ———,
By ——— ———,
——— ———,
——— ———.

Reference : ——— ———.
Post-office address : ——— ———.

REPORT OF EXPERIMENTS IN WOOD SEASONING.

CHEMICAL LABORATORY,
Aurora, Ill., January 9, 1889.

Mr. G. W. RHODES,
Superintendent M. P., Chicago and Burlington R. R. Co.:

DEAR SIR: Herewith is submitted a report on a second series of "experiments in the fluctuation of moisture in wood during seasoning," a report on first series having been submitted March 2, 1887. Accompanying this are diagrams showing the weekly fluctuation of the moisture for every piece used during the experiments, based upon the exact percentages of moisture in the tables given herein. In the diagrams the nearest to a whole per cent. was taken.

The object of this second series was to corroborate, if possible, the conclusions of the first series, viz: (1) To determine the time that outdoor seasoning begins and ends as indicated by the moisture; (2) to ascertain whether the wood will again take back moisture during the wet seasons of the fall and spring; (3) effects of size of wood; and (4) whether one season is sufficient to season wood.

To determine these questions, fifteen pieces of unseasoned timber, as wet as could be obtained, were placed out of doors in a latticed shed, and loosely piled with cleats between and a board topping, all to protect from direct dripping and rain, and yet to be under the same conditions as outdoor seasoned lumber.

All of the oak was from Kentucky, the pine from Michigan, ash from Arkansas, white-wood from Tennessee, and elm from Michigan.

The first lot of lumber, including all but the pine, was received Wednesday, December 29, 1886, and the first determination of moisture made Monday, January 3, 1887. The four pines were received later, the first moisture determination being made April 18, 1887. The following are the determinations and the kind of material:

Letter.	Kind.	For what used.	Cross dimensions.	Length.	
			In. *In.*	*Ft.*	*In.*
A	Oak	Draw wood	4¾ by 14	17	0
F	do	do	4½ by 8	8	2
D	do	End plate	3½ by 12½	9	3
E	do	End sill	5 by 9½	9	6
J	do	do	9 by 9½	10	0
K	do	Corner post	4 by 5	7	4
G	do	Draw beam	9¼ by 9½	12	2
I	do	Side brace	3 by 4½	7	0
B	Ash	Corner post	4 by 9	16	0
C	White-wood	Outside	3 by 12	16	0
H	Elm	Brake beam	4½ by 6½	12	0
L	Hard pine	Flooring	2 by 10	18	0
M	Soft pine	Roofing	1 by 6	16	0
N	Hard pine	Side sill	5 by 9½	30	0
O	do	Side plate	2½ by 5	30	0

There are yet running two pieces of pine (N and O), and when they are finished a third report will be made on "fluctuation of moisture in wood and miscellaneous experiments in wood seasoning."

On every Monday morning the amount of moisture was determined. Following is the method employed in the estimation: From the same end of each piece, exactly 3 inches was sawed, and from this piece on the end freshly sawed, and exactly in the center, borings of the wood were obtained, using a ⅝-inch bit. These borings or chips were transferred, as quickly as they left the bit, to a previously weighed drying tube, and when about 2½ inches had been bored, the tube is quickly and securely stopped and again weighed. The amount of chips of the wood is then known. This tube containing the chips is placed in an air-oven for one hour, at a temperature of 230 degrees Fahrenheit; then taken out, cooled and weighed. This is repeated, drying fifteen minutes each time, until the weight begins to increase (due perhaps to oxidation of the resinous matters), when the lowest weight obtained is taken as the correct one. The determinations were all made by the same person, except a few during March and April, 1888, and thus any "personal error" avoided that might arise from different persons doing the work.

COMMENTS.

Oak.—It will be noticed in the tables of percentages of moisture that determinations were made in eight pieces of oak of different dimensions, only one of which (A) was of sufficient length to last more than one year. In this piece the moisture fluctuated very much, although there is noticeable decrease commencing in April, and being the lowest the latter part of November, when it increased from 30 per cent. to 35 per cent., and then went down again until it ended in March. I do not attribute the 5 per cent. increase in December to the wood absorbing moisture, but to the fact that the per cent. of moisture in the center or heart of green oak would amount to this difference. An experiment was made on oak to determine this point, a report of which will be given in the third series. In oak G (dimension 9½ inches by 9½ inches by 12 feet 2 inches), the moisture at start in January was 43 per cent., and commenced to drop in March and April and in the following months until the end in November, fluctuating between 38 per cent. and 41 per cent. The remaining oak (K, F, I, D, J, and E) all commence to decrease in percentage of moisture during March and April, and show a continual decrease toward the end of the pieces. Unfortunately these pieces were not of sufficient length to allow the moisture to reach the lowest limit, but from them we can tell the spring months which the seasoning begins.

Pine.—Experiments with the pines were not commenced until April 18, 1887, and two test pieces (N and O) are still under observation. In these there is an almost immediate decrease in percentage of moisture. In N, the moisture dropped from 28 per cent. in April to 12 per cent. October 1, when it increased to about 16 per cent., remaining at that through the full winter and spring, and in the following May again began to decrease until 13 per cent. was reached, where it remained with slight variation. In O, the moisture in April, 1887, was 20 per cent., and by the following August, 1887, had dropped to 9 per cent., then increased to about 14 per cent., where it remains with the exception of a slight drop in the summer.

Months of 1888: The piece of roofing, 1 inch thick, had 14 per cent. of moisture in April, 1887, and which decreased to 10 per cent. by August, but the following fall and winter months it increased to 16 per cent., and did not decrease during the winter and spring months, until August, 1888, when it commenced to drop, and by June, 1888, the percentage was about the same as the summer of 1887. This piece took up moisture during the wet seasons.

The pine L (2 inches by 10 inches by 18 feet) when first commenced in April contained 18–20 per cent. moisture, but immediately began to decrease and reached the lowest percentage of moisture in the following July and August, then increased during the fall and winter, amounting to 17 per cent. during February and March of 1888, and again beginning to decrease in April and continuing to do so until the piece ended in the middle of July. The piece also took up moisture during the wet seasons.

Ash.—Only one piece of ash was used during the experiments, which contained about 22 per cent. of moisture during the months of January, February, and March, but during April the percentage began to decrease, being the lowest in August (11 per cent.) and remained at about 12 per cent. during the following fall and winter months, and until March, 1888, when the piece ended.

Elm.—The one piece of elm, H, showed a steady decrease of moisture from 29 per cent. in January, 1887, to 16 per cent. in November of the same year, when the end of the piece was reached.

White-wood.—This wood, C, had 16 per cent. of moisture in January, 1887, and began to decrease in April, reaching the lowest (10 per cent.) in July and August, and varied but 1 or 2 per cent. during the remainder of the period of observation, which ended the middle of November of the same year.

Percentages of moisture.

Date.	Oak.	Ash.	White wood.	Oak.				Elm.	Oak.			Pine.			
	A.	B.	C.	D.	E.	F.	G.	H.	I.	J.	K.	L.	M.	N.	O.
1887.															
Jan. 3	33.66	19.79	16.21	46.56	44.23	38.75	43.21	28.51	47.23	37.75	42.90	......	......	......	......
10	36.53	22.31	14 80	46.09	45 07	40.00	42.94	28.21	44.33	37.98	43 00	......	......	......	......
17	38.72	22.35	15.78	46.83	45.60	40.37	42.22	28.59	44.67	38.74	43.07	......	......	......	......
21	40.73	22.42	15.52	46.25	45.41	40.28	42.08	27.83	41.63	37.77	43.26	......	......	......	......
31	40.56	22.60	14.31	43.33	43.90	40.08	44.32	27.12	43.80	38.99	42.17	......	......	......	......
Feb. 7	41.85	22.44	15.11	45.57	43.90	39.18	43.51	27.35	44.50	35.99	42.17	......	......	......	......
14	42.99	22.37	15.72	46.47	43.79	41.03	42 92	28.03	44.69	37.89	42.66	......	......	......	......
21	43.13	22.59	15.89	46.38	42.92	39.29	42.30	27.51	43.93	37.93	42.18	......	......	......	......
28	43.78	22.49	15.03	46.20	43.31	39.48	42.80	27.39	44.59	38.85	42.69	......	......	......	......
Mar. 7	42.11	21.67	15.45	43.64	42.88	38.47	42.10	26.85	42.70	39.00	41.36	......	......	......	......
14	42.81	20.84	15.33	43.04	43.19	38.20	40.29	25.57	42.31	37.23	40.65	......	......	......	......
21	42.63	21.02	15.32	45.11	43.82	38.41	40.28	24.46	42.61	37.56	43.83	......	......	......	......
28	43.14	21.24	15.54	46.62	44.08	37 82	40.97	24 42	42.85	35.87	40.31	......	......	......	......
Apr. 4	43.61	21.26	15.21	44.57	43.38	37.37	40.05	24.28	41.65	35.74	40.48	......	......	......	......
11	42.85	23.26	13.98	45.56	42.26	38.50	39.62	23.60	40.76	37.09	40.22	......	......	......	......
18	41.83	19.08	13.36	43.77	42.27	38.61	39.62	23.47	40.57	36.03	40.18	17.58	13 58	23.37	21.21
24	43.02	20.61	14.06	40.53	41.57	39.37	40.30	23.14	41.49	38.15	40.52	19.56	14.11	29.18	21.27
May 2	40.08	18.76	12.26	40.03	41.85	28.04	38.81	22.67	39 87	36.55	39.62	17.09	12.52	28.61	18.31
9	40.65	18.32	12.01	40.43	41.84	38.40	38.38	22.91	40.97	38.19	39.55	15.47	12.42	28.32	16.32
16	39.80	17.31	11.51	39.59	42.11	38.21	39.45	22.34	39.[illegible]	38.72	39.41	13.56	11.22	26.27	14.11
23	39.95	16.88	11.10	40.68	41.34	36.82	38.34	21.69	38.94	38.42	39.51	12.69	12.64	22.77	14.22
30	39.52	16.42	11.78	41.45	41.81	37.24	37.61	22.12	39.06	37.67	39.19	13.88	8.99	27.42	14.32
June 6	45.44	16.34	12.47	42.62	41.31	37.38	38.70	21.58	38.44	36.95	38.93	15.21	14.25	25.19	15.15
13	35.96	15.87	12.19	40 97	41.01	37.71	38.94	21.23	36.63	36.11	38.22	14.65	12.17	24.24	13.29
20	39.39	14.30	11.19	40.50	40.15	37.06	36.60	20.50	34.71	34.20	38.16	13.29	11.71	19.00	10.06
27	40.10	13.91	10.40	40.49	40.41	37.28	35.30	20.16	33.11	33.63	37.07	12.72	11.36	19.82	10.52
July 4	39.78	13.31	11.34	35.51	41.12	36.56	39.03	20.20	32.56	34.65	35.57	12.79	12.54	19.05	11.25
11	40.67	13.21	11.05	34.70	41.72	35.52	38.60	19.48	31.28	36.56	32.32	12.48	12.70	20.80	9.61
18	37.76	12.61	10.46	32.47	41.22	35.89	40.65	19.23	24.43	34.76	24.57 End.	11.50	10.31 (*)	16.67	9.43
25	41.40	13.00	10.95	34.19	41.68	34.93	40.06	18.94	29.48	34.83	......	12.43	10.82	21.28	9.98
Aug. 1	40.81	11.32	9.26	31.57	39.66	31.46	39.21	17.64	21.98	35.13	......	10.89	9.70	19.47	8.64
7	37.81	13.15	9.81	33.42	39.67	21.17 End.	40.31	18.50	21.98 End.	37.72	......	11.01	9.88	19.59	8.82
15	39.15	12.69	10.55	30.56	39.68	......	40.58	17.92	......	36.80	......	11.92	11.63	17.73	10.55
22	40.49	12.36	11.56	29.50	38 92	......	40.44	17.31	......	36.09	......	12.60	11.12	15.83	10.58
29	38.43	12.45	11.22	25.66	36.38	......	41.29	17.65	......	37.32	......	13.02	11.86	16.65	10.89
Sept. 5	38.65	11.37	10.73	23.77 End.	36.88	......	40.52	16.93	......	36.94	......	12.03	11.10	15.84	10.40
12	37.37	12.23	10.80	......	34.70 End.	......	40.67	16.38	......	35.96	......	12.62	11.83	14.79	10.92
19	34.94	11.18	10.35	......	......	......	38.68	16.25	......	30.60	......	11.90	11.10	13.41	10.16
26	36.11	12.43	11.11	......	......	......	40.02	16.61	......	26.00 End.	......	12.90	12.01	14.18	11.29
Oct. 3	36.37	12.69	12.84	......	......	......	40.42	16.53	......	......	......	13.86	16.26	12.25	13.38
10	35.51	12.43	12.44	......	......	......	40.86	16.12	......	......	......	14.01	15.43	15.04	12.98
17	35.60	12.10	11.81	......	......	......	39.34	16.75	......	......	......	16.62	13.72	14.34	12.07
24	34.32	12.25	11.93	......	......	......	38.46	16.26	......	......	......	13.14	13.94	14.91	12.95
31	34.07	12.34	11.81	......	......	......	38.58	16.36	......	......	......	13.29	13.26	14.00	13.01
Nov. 7	32.77	12.04	11.29	......	......	......	35.09	16.25	......	......	......	12.70	12.54	13.73	15.03
14	32.28	11.95	11.50	......	......	......	36.68	15.15	......	......	......	12.99	12.43	14.78	12 64
21	33.44	12.23	8.39 End.	......	......	......	37.11	15.58	......	......	......	14.48	13.12	14.93	9.39
28	30.26	16.68	......	......	......	......	32.36 End.	12.70 End.	......	......	......	13.23	13.59	14.94	13.79
Dec. 5	31.43	12.70	......	......	......	......	......	......	......	......	......	13.09	13.77	14.88	13 58
12	33.03	13.03	......	......	......	......	......	......	......	......	......	14.00	14.73	15.12	14 67
19	33.60	12.80	......	......	......	......	......	......	......	......	......	13.64	14.78	14.78	13.57
26	34.46	12.80	......	......	......	......	......	......	......	......	......	13.99	14.26	14.47	13.48
1888.															
Jan. 1	34.21	13.09	......	......	......	......	......	......	......	......	......	14.46	14.53	13.30	14.00
9	34.81	13.56	......	......	......	......	......	......	......	......	......	14.97	16.10	15.56	14.78
16	34.82	13.71	......	......	......	......	......	......	......	......	......	15.11	16.32	15.38	14.59
23	34.22	13.23	......	......	......	......	......	......	......	......	......	15.43	15.81	15.39	14.25
30	33.58	12.69	......	......	......	......	......	......	......	......	......	15.42	16.31	15.79	14.17

Percentages of moisture—Continued.

Date.	Oak.	Ash.	White wood.	Oak.				Elm.	Oak.			Pine.			
	A.	B.	C.	D.	E.	F.	G.	H.	I.	J.	K.	L.	M.	N.	O.
1888.															
Feb. 5	33 30	12.97	......	......	......	......	......	......	......	......	......	16.20	16.35	15.72	14 01
13	32.65	13.20	......	......	......	......	......	......	......	......	......	16.61	16.48	16.26	14.25
20	32.01	13.20	......	......	......	......	......	......	......	......	......	15.95	11.48	13.58	13 98
27	30.66	12.85	......	......	......	......	......	......	......	......	......	16.17	15.78	15.89	14.16
Mar. 5	30.08	12.57	......	......	......	......	......	......	......	......	......	16.65	15.19	16.14	14.08
		End.													
12	28.69	......	......	......	......	......	......	......	......	......	......	16.47	14.65	15.79	13.89
19	22.32	......	......	......	......	......	......	......	......	......	......	16.01	15.80	15.41	13.43
	End.														
26	......	......	......	......	......	......	......	......	......	......	......	16.13	15.22	15.61	13.79
Apr. 2	......	......	......	......	......	......	......	......	......	......	......	......	15.03	16.18	15.26
9	......	......	......	......	......	......	......	......	......	......	......	15.85	13.51	15.29	12.80
16	......	......	......	......	......	......	......	......	......	......	......	15.84	13.38	14.95	12.62
23	......	......	......	......	......	......	......	......	......	......	......	16.00	13.50	15.54	12.95
30	......	......	......	......	......	......	......	......	......	......	......	14.19	11.00	15.22	14.07
May 7	......	......	......	......	......	......	......	......	......	......	......	15.04	11.80	15.79	13.47
14	......	......	......	......	......	......	......	......	......	......	......	15.07	12.27	15.95	12.72
21	......	......	......	......	......	......	......	......	......	......	......	14.64	11.71	15.90	12 82
28	......	......	......	......	......	......	......	......	......	......	......	13.99	12.18	15.49	12.53
June 4	......	......	......	......	......	......	......	......	......	......	......	13.81	11.46	14.23	12.14
11	......	......	......	......	......	......	......	......	......	......	......	13.86	11.36	14.29	12.29
18	......	......	......	......	......	......	......	......	......	......	......	12.97	10.30	13.39	11.38
													End.		
25	......	......	......	......	......	......	......	......	......	......	......	14.42	......	13.14	11.25
July 2	......	......	......	......	......	......	......	......	......	......	......	12.63	......	13.16	11.44
9	......	......	......	......	......	......	......	......	......	......	......	12.95	......	13.98	12.32
16	......	......	......	......	......	......	......	......	......	......	......	12.73	......	12.71	11.87
23	......	......	......	......	......	......	......	......	......	......	......	11.93	......	12.30	11.46
30	......	......	......	......	......	......	......	......	......	......	......	12.11	......	12.56	11.92
Aug. 6	......	......	......	......	......	......	......	......	......	......	......	12.21	......	12.32	11.57
13	......	......	......	......	......	......	......	......	......	......	......	11.24	......	13.25	11.52
20	......	......	......	......	......	......	......	......	......	......	......	11.68	......	12.67	11.54
												End.			
27	......	......	......	......	......	......	......	......	......	......	......	......	......	12.90	11.91
Sept. 3	......	......	......	......	......	......	......	......	......	......	......	......	......	11.79	10.84
10	......	......	......	......	......	......	......	......	......	......	......	......	......	11.34	10.81
17	......	......	......	......	......	......	......	......	......	......	......	......	......	12.63	11.16
24	......	......	......	......	......	......	......	......	......	......	......	......	......	12.70	12.60
Oct. 1	......	......	......	......	......	......	......	......	......	......	......	......	......	11.87	12.04
8	......	......	......	......	......	......	......	......	......	......	......	......	......	12.69	12.70
15	......	......	......	......	......	......	......	......	......	......	......	......	......	12.53	11.89

NOTE.—In the "starred" percentage on y. pine "M," the cut was made 1 foot from previous one on account of knot. Pieces "N" and "O" have 10 feet yet to be cut. The diagrams were made on percentages up to October 29, 1888.

CONCLUSION.

Out door seasoning depends a great deal on the character of the weather during the year, that is, as to an early or late spring or fall, hot or cold summer months, or severe winter, etc., but during the experiments it may be considered to have been average Illinois weather.

The result of this series of experiments shows that the month during which the seasoning begins varies with the kind of wood.

(1) That for oak the seasoning commences in March or April; with pine the exact month can not be decided, as they were not placed under observation until late (April), but all test pieces showed a loss of moisture within a fortnight after being exposed.

Ash and white-wood commenced to lose moisture in April, and elm immediately on being exposed in January.

No law can be deduced from the experiments as to the exact time that seasoning ends, as the woods all vary, but as a general rule it may be stated that in all woods (except perhaps elm) seasoning virtually ends with the end of the summer months.

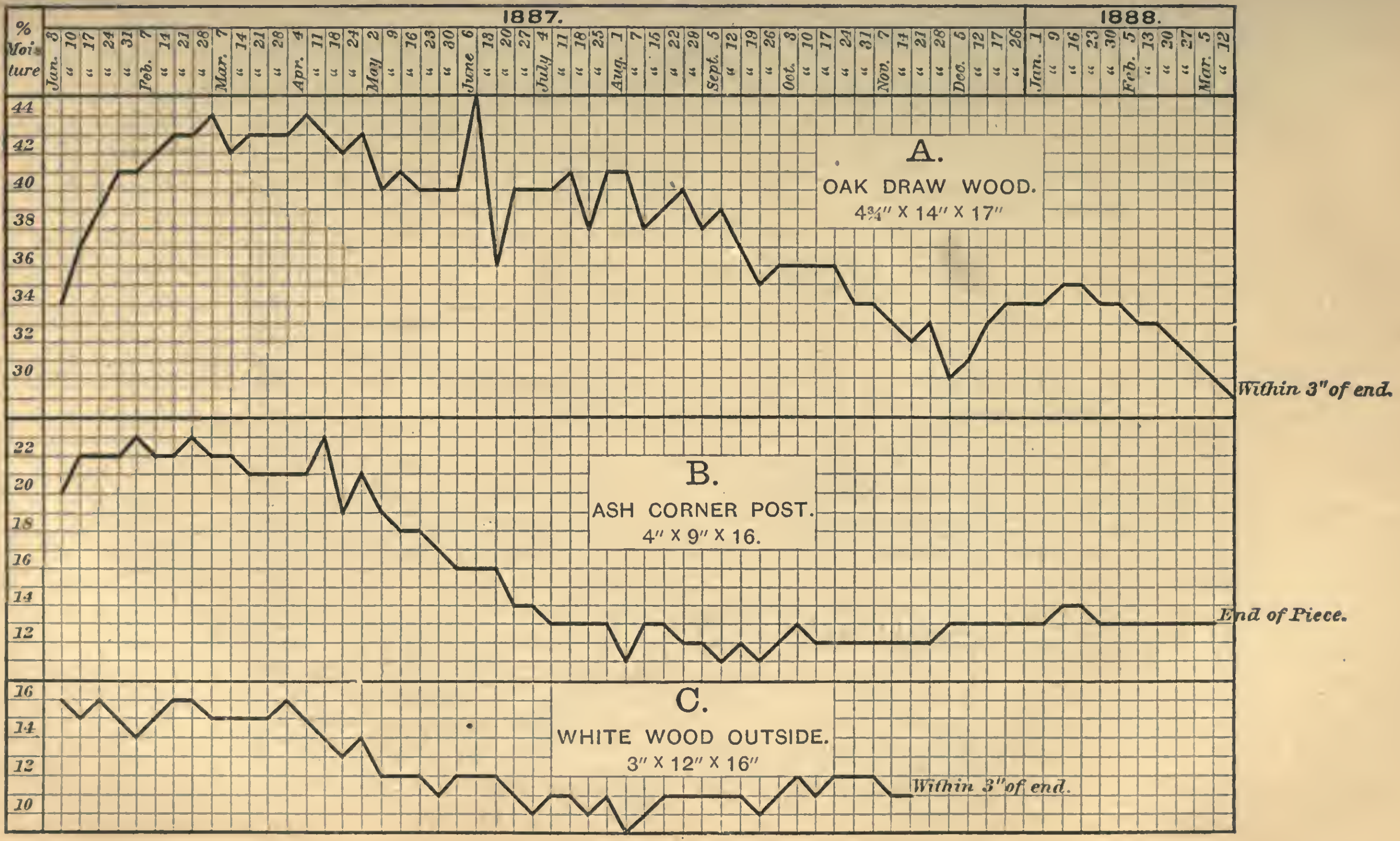
(2) All woods take up moisture in slight amounts during wet weather of the fall and winter months.

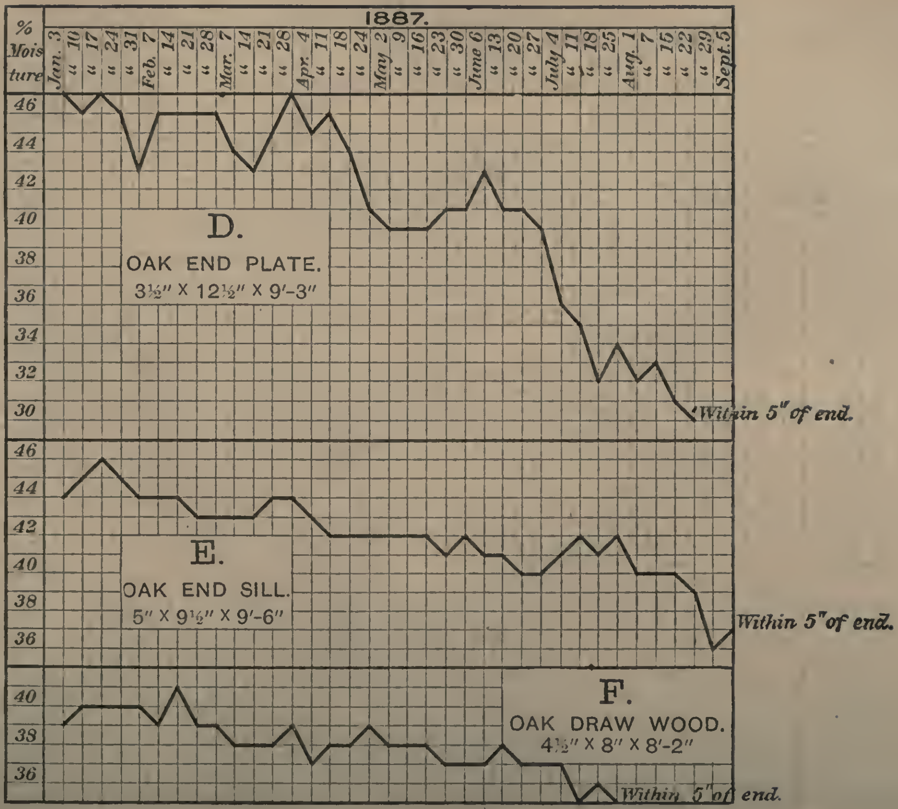
(3) Pine of small dimensions (such as 1 inch flooring "M") will absorb moisture during the wet months. Other woods of small dimensions were not experimented with.

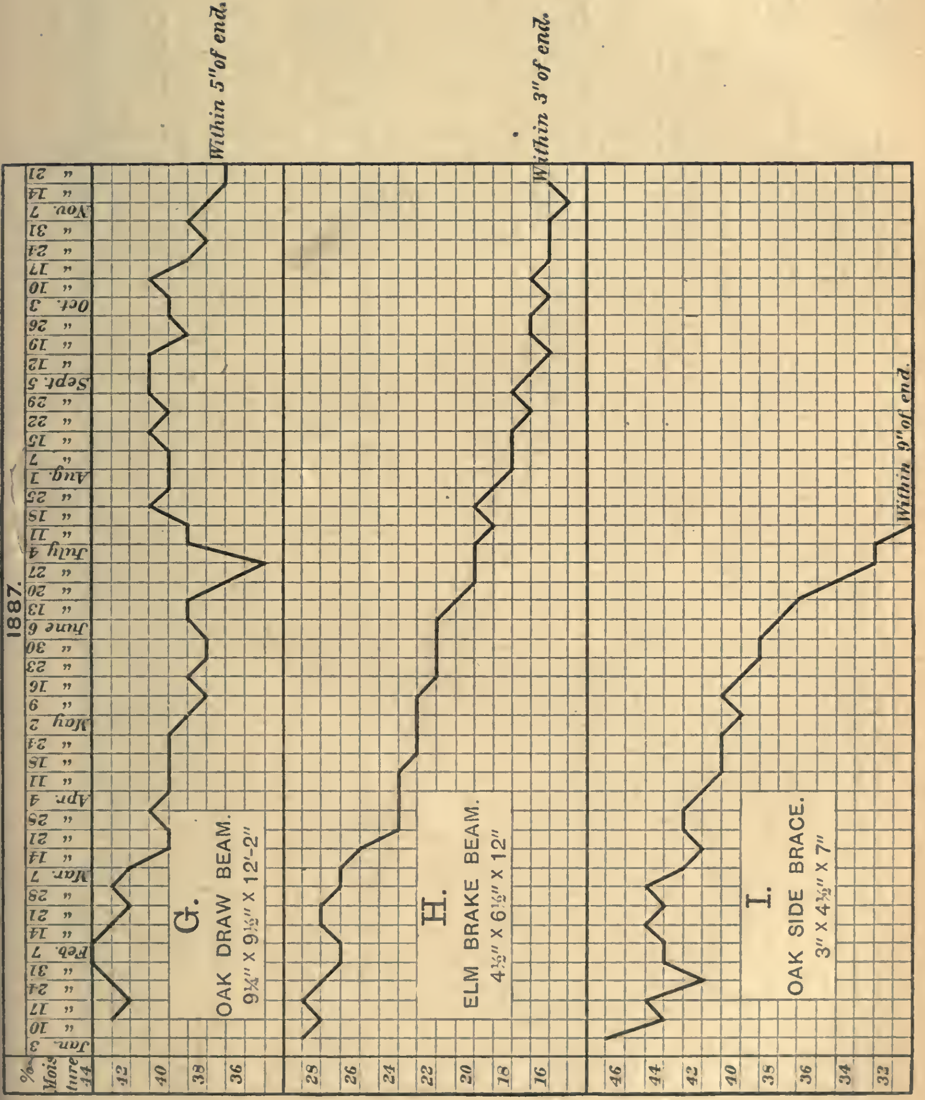
(4) As shown by these experiments one season of average weather is generally sufficient to season woods for purposes of construction.

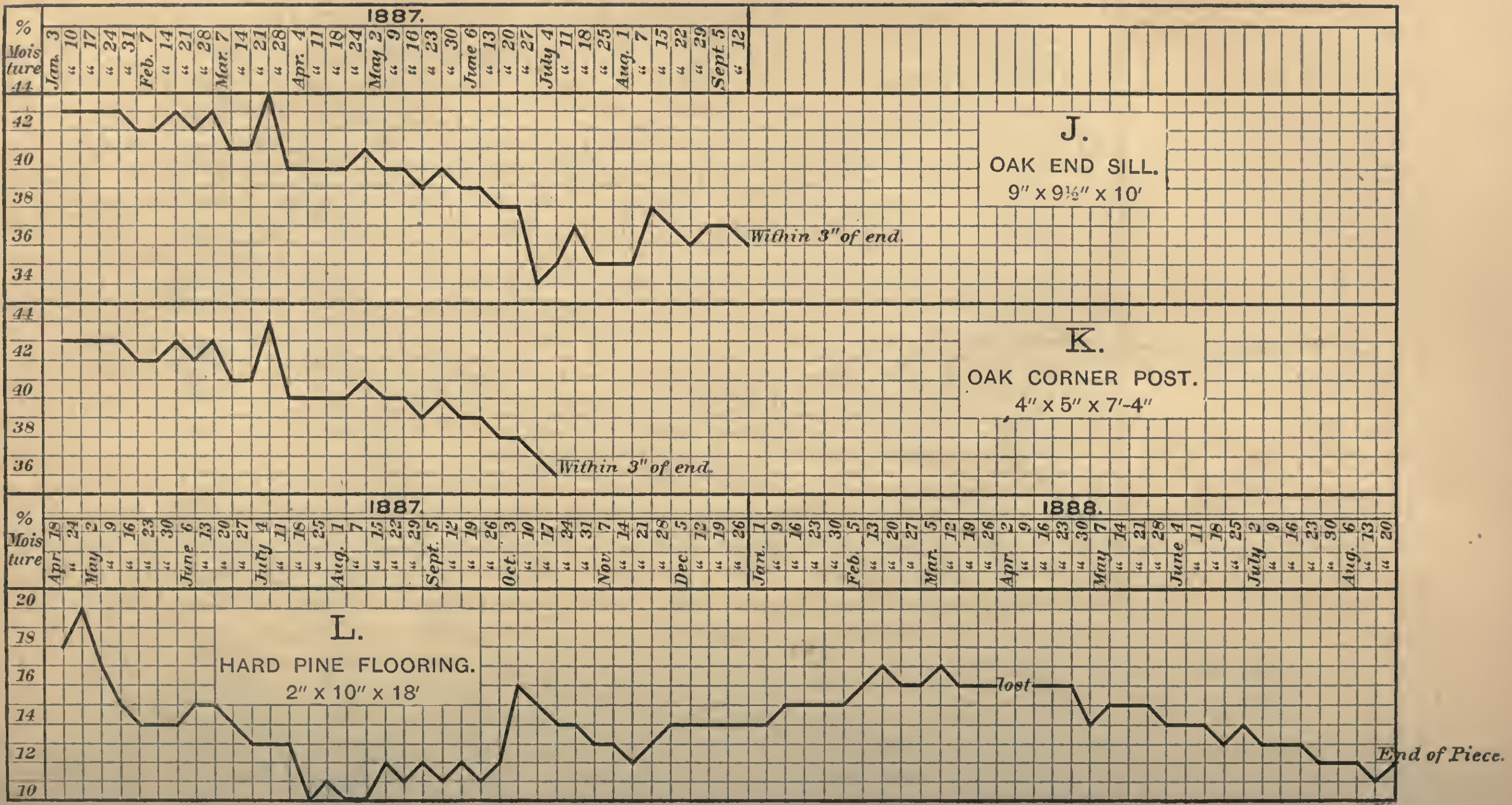
Yours truly,

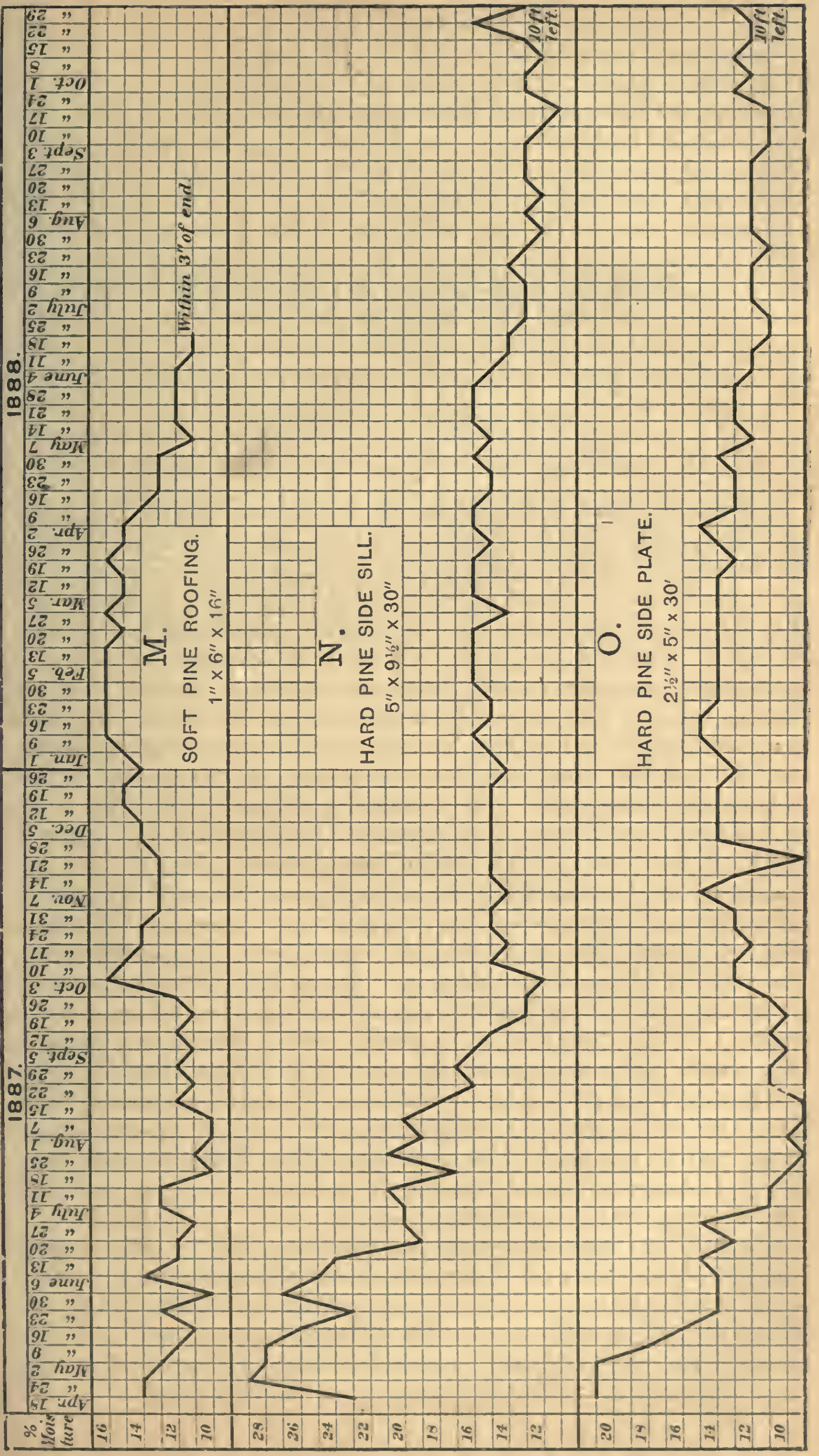
G. H. Ellis,
Chemist.


% Moisture
1887.
1888.
Jan. 8
" 10
" 17
" 24
" 31
Feb. 7
" 14
" 21
" 28
Mar. 7
" 14
" 21
" 28
Apr. 4
" 11
" 18
" 24
May 2
" 9
" 16
" 23
" 30
June 6
" 18
" 20
" 27
July 4
" 11
" 18
" 25
Aug. 1
" 7
" 15
" 22
" 29
Sept. 5
" 12
" 19
" 26
Oct. 3
" 10
" 17
" 24
" 31
Nov. 7
" 14
" 21
" 28
Dec. 5
" 12
" 17
" 26
Jan. 1
" 9
" 16
" 23
" 30
Feb. 5
" 13
" 20
" 27
Mar. 5
" 12
44
42
40
38
36
34
32
30
22
20
18
16
14
12
16
14
12
10
A.
OAK DRAW WOOD.
4¾″ X 14″ X 17″
Within 3″ of end.
B.
ASH CORNER POST.
4″ X 9″ X 16.
End of Piece.
C.
WHITE WOOD OUTSIDE.
3″ X 12″ X 16″
Within 3″ of end.


1887.
% Moisture
Jan. 3
" 10
" 17
" 24
" 31
Feb. 7
" 14
" 21
" 28
Mar. 7
" 14
" 21
" 28
Apr. 4
" 11
" 18
" 24
May 2
" 9
" 16
" 23
" 30
June 6
" 13
" 20
" 27
July 4
" 11
" 18
" 25
Aug. 1
" 7
" 15
" 22
" 29
Sept. 5
46
44
42
40
38
36
34
32
30
D.
OAK END PLATE.
3½" X 12½" X 9'-3"
Within 5" of end.
46
44
42
40
38
36
E.
OAK END SILL.
5" X 9½" X 9'-6"
Within 5" of end.
40
38
36
F.
OAK DRAW WOOD.
4½" X 8" X 8'-2"
Within 5" of end.


1887.
% Moisture
Jan. 3
" 10
" 17
" 24
" 31
Feb. 7
" 14
" 21
" 28
Mar. 7
" 14
" 21
" 25
Apr. 4
" 11
" 18
" 24
May 2
" 9
" 16
" 23
" 30
June 6
" 13
" 20
" 27
July 4
" 11
" 18
" 25
Aug. 1
" 7
" 15
" 22
" 29
Sept. 5
" 12
" 19
" 26
Oct. 3
" 10
" 17
" 24
" 31
Nov. 7
" 14
" 21
44
42
40
38
36
28
26
24
22
20
18
16
46
44
42
40
38
36
34
32
G.
OAK DRAW BEAM.
9¼" X 9½" X 12'-2"
Within 5" of end.
H.
ELM BRAKE BEAM.
4½" X 6½" X 12"
Within 3" of end.
I.
OAK SIDE BRACE.
3" X 4½" X 7"
Within 9" of end.


1887.
% Moisture
Jan. 3, 10, 17, 24, 31, Feb. 7, 14, 21, 28, Mar. 7, 14, 21, 28, Apr. 4, 11, 18, 24, May 2, 9, 16, 23, 30, June 6, 13, 20, 27, July 4, 11, 18, 25, Aug. 1, 7, 15, 22, 29, Sept. 5, 12
44, 42, 40, 38, 36, 34
J.
OAK END SILL.
9" x 9½" x 10'
Within 3" of end.
44, 42, 40, 38, 36
K.
OAK CORNER POST.
4" x 5" x 7'-4"
Within 3" of end.
1887.
1888.
% Moisture
Apr. 18, 24, May 2, 9, 16, 23, 30, June 6, 13, 20, 27, July 4, 11, 18, 25, Aug. 1, 7, 15, 22, 29, Sept. 5, 12, 19, 26, Oct. 3, 10, 17, 24, 31, Nov. 7, 14, 21, 28, Dec. 5, 12, 19, 26
Jan. 1, 9, 16, 23, 30, Feb. 5, 13, 20, 27, Mar. 5, 12, 19, 26, Apr. 2, 9, 16, 23, 30, May 7, 14, 21, 28, June 4, 11, 18, 25, July 2, 9, 16, 23, 30, Aug. 6, 13, 20
20, 18, 16, 14, 12, 10
L.
HARD PINE FLOORING.
2" x 10" x 18'
lost
End of Piece.


% Moisture
1887.
1888.
Apr. 18
" 24
May 2
" 9
" 16
" 23
" 30
June 6
" 13
" 20
" 27
July 4
" 11
" 18
" 25
Aug. 1
" 7
" 15
" 22
" 29
Sept. 5
" 12
" 19
" 26
Oct. 3
" 10
" 17
" 24
" 31
Nov. 7
" 14
" 21
" 28
Dec. 5
" 12
" 19
" 26
Jan. 1
" 9
" 16
" 23
" 30
Feb. 5
" 13
" 20
" 27
Mar. 5
" 12
" 19
" 26
Apr. 2
" 9
" 16
" 23
" 30
May 7
" 14
" 21
" 28
June 4
" 11
" 18
" 25
July 2
" 9
" 16
" 23
" 30
Aug. 6
" 13
" 20
" 27
Sept. 3
" 10
" 17
" 24
Oct. 1
" 8
" 15
" 22
" 29
16
14
12
10
28
26
24
22
20
18
16
14
12
20
18
16
14
12
10
M.
SOFT PINE ROOFING.
1" x 6" x 16'
Within 3" of end.
N.
HARD PINE SIDE SILL.
5" x 9½" x 30'
10 ft left.
O.
HARD PINE SIDE PLATE.
2½" x 5" x 30'
10 ft left.

THE RELATION OF RAILWAYS TO THE TIMBER RESOURCES OF THE UNITED STATES.

By E. E. Russell Tratman, C. E.

(Read before the American Forestry Congress, at Atlanta, Ga., December 8, 1888.)

The report of the Commissioner of Agriculture for 1887, recently published, contains an interesting but brief report from the Chief of the Forestry Division, and this report refers to the Government interest in the development and maintenance of the forests; a matter which is of far greater importance than is generally understood, and which is especially important on account of the rapid destruction of forests through the legitimate demand for timber, through reckless use, and through wasteful practices of burning, herding, etc., while very little practical attention is paid to the question of forest planting or reforesting, although the forest under proper management is capable of furnishing continuous crops. The question considered is, "What is the first duty of the General Government in regard to the forestry question?" It is stated that the natural forests are being rapidly reduced by an increased demand for timber and by reckless use and wanton destruction, and that the annual consumption of wood and wood products is at least double the amount reproduced on our present forest area. The national interest in this question is shown from four points of view: (1) Because the forests properly managed would be the source of a constant supply of timber; (2) because a sound land policy demands attention to forest management to prevent the deterioration of forests and forest lands; (3) because a rational forest policy demands attention to the disturbance of the distribution of water flow by forest devastation and by the denudation of mountains and hills; and (4) because forest planting is a means of ameliorating climatic conditions and making certain regions more habitable.

Other nations have recognized the importance of the forestry problem and have the matter under State administration; for private interest is not sufficient to protect the forest property, since to the individual it is the existing timber alone that is valuable, and he has no care for any but pecuniary considerations. Consequently the State must undertake the management and protection of the forests.

The General Government of the United States owns about 50,000,000 to 70,000,000 acres of forest area, principally in the far West and on the Pacific ranges, and mostly on land not fit for agricultural purposes. The water supplies for the valleys and the agricultural areas of these regions are regulated and influenced to a great extent by the forests, and it is therefore obvious that the matter of preservation and protection of the forests is one of importance to the national prosperity; whereas, in fact, the timber is recklessly used and wasted, while the attempts to prevent the waste are practically ineffectual. A bill to protect the Government forests has, however, been submitted to Congress. The report referred to shows very forcibly the need of legislation in this direction, and of proper management to regulate the cutting, to attend to the maintenance and protection, and to undertake the planting of new forests to furnish a future supply of timber.

Of course these remarks apply to the consumption in total, but the railways are responsible to a considerable extent, both on account of the immense amount legitimately consumed for ties, bridges, trestles, buildings, etc., and on account of their waste and the amount improperly acquired. The report states as follows:

> Every land-grant railway, in addition to its share of the land grant of 75,000,000 acres and the right of way, is permitted to cut timber "for first construction, adjacent to the line of its road." But the railways do not consider "construction" and "adjacent" exactly in the sense in which the lawgivers did, and they have cut wherever, whenever, and for what purpose they chose.

Railway men as a rule do not give much attention to the sources of supply for ties, but, with others, believe blindly in "inexhaustible" forests, or if they do look forward at all to a diminished supply, they usually consider it as too far in the future to require any special attention now. In point of fact, however, this is even now a very important matter, which becomes more serious every year. Forests, although they can be made to furnish regular annual crops, can not be grown in a year, and while present resources are being recklessly drawn upon, few steps are being taken to provide future resources.

There are four ways in which the railways may help to economize the present supply: (1) By taking more care in the selection, cutting, and storing of timber; (2) by the more general use of iron, steel, stone, brick, concrete, etc., for bridges, trestles, buildings, and other construction works; (3) by the introduction of some efficient and economical preservative process; and (4) by the introduction of metal cross-ties. These four methods of economizing will be considered separately.

1. *By taking more care in the selection, cutting, and storing of timber.*—Sufficient investigation has not been made of the availability of different kinds of timber for railway work. For instance, there are probably other kinds of timber besides those now used which are suitable for ties, and, in fact, a circular was issued some months ago by the Forestry Division* showing the advantages of the hitherto unused chestnut

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*See Circular on p. 52.

oak, a species of timber of which the bark was used, but the wood itself left to rot, its value for railway ties not being known or appreciated. As a result of this circular, large numbers of ties have now been made from this wood. Certain specifications for ties which have been published name only the following varieties:

> Oaks of the various kinds, known as "white," "black," "yellow," "rock," "burr," and "post" (no red oak will be received), second-growth white chestnut, red beech, red elm, cherry, maple, butternut, tamarack, and yellow pine of the long-leaved southern hard pine variety, cut from untapped trees and grown not north of South Carolina. Hemlock may be accepted, but only under special contracts.

But it has been suggested that red oak, black locust, and white and red cedar might be added, and probably others, besides the chestnut oak already referred to. This part of the question is important also in connection with the third part, as the use of preservatives may enable other kinds of timber to be used. It is sometimes specified that there is to be no sap-wood on the face of the ties, which excludes all ties cut from such trees as give only one tie, often the best. With regard to cutting, although over this the railway has often no control, except in the case of new roads through timber country, there is undoubtedly much timber wasted in high stumps and by careless felling, etc., which with a little care might have been available for ties or lumber. In storing, the ties are often stacked up in close piles, without any air-spaces between adjacent ties, and left till wanted, by which time many will probably be found, especially at the bottom of the pile, to be rotten and useless. If they were thrown into a pond or brook, of course under proper supervision, their life when put in the track would be longer than if they had been stacked. Bridge timbers and other lumber should also be properly cared for in storage.

2. *The more general use of iron, steel, stone, brick, concrete, etc., for bridges, trestles, buildings, and other construction works.*—On this point much need not be said. Iron and steel are becoming more and more generally used for bridges and trestles, and many large and some small stations are now built of masonry. There is, however, room for very much greater economy yet to be practiced in the use of timber for railway structures, and it will be practiced more as companies grasp the idea that a heavy outlay in the first place is often economical. This, of course, applies only where the heavy first cost can be afforded; but it applies extensively to wealthy corporations, which continue to spend money and use timber in building and repairing timber trestles, sheds, wharves, etc., instead of laying out a good round sum on permanent works. In this respect much might be learned from European practice.

3. *The introduction of some efficient and economical preservative process.*—Numerous preservative processes have been experimented with and large quantities of preserved ties, piles, and lumber used; but considering the enormous quantity of timber in use on the railways of this country, the step towards economy in this direction is a very insignifi-

cant one. The trouble is to find a good process and to get it thoroughly carried out. Different species of timber and different pieces of the same timber absorb different quantities of the preservative, thus producing an undesirable want of uniformity. This is specially troublesome in the case of ties, some ties lasting for years and others having to be replaced in a short time, which means considerable expense for maintenance of the track. In England, where the creosoting process is generally adopted for ties, some railway companies have their own plant and creosote their own ties, sometimes also sawing their own ties from logs delivered by contract. Some of these plants were described in my paper on "English Railway Track," read at the annual convention of the American Society of Civil Engineers at Milwaukee, Wis., in June, 1888. Too little practical attention has been given to this question, though it seems as if some slow progress was being made. Creosoting is very generally used in England and is very successful, but the kind of creosote used is more expensive in this country. Some very valuable and useful information on this subject is contained in the report of the committee on the preservation of timber, American Society of Civil Engineers, June, 1885, and in Bulletin No. 1 of the Forestry Division for 1887.

4. *By the introduction of metal cross ties.*—This subject, one of the most important in railway matters, from the point of view of the economy and efficiency of the track for operation and maintenance as well as from that of economy in timber, is not given much practical attention in this country. Comparatively little is known in detail of what has been done and is being done in other parts of the world, though it is usually understood that quite a number of experiments have been made in foreign countries. Experiments certainly have been made and are still being made, but the matter, on the whole, is beyond the experimental stage, and metal ties have been regularly adopted on hundreds of miles of track, with most satisfactory results. The reason why the matter has been so neglected in this country, may probably be found in the undeniable *cheapness* of so many of our railways; the fact being frequently overlooked that cheapness is expensive, and that what is saved in construction is paid out over and over again in maintenance and expenses. By this it is not meant to suggest that every road should at once put down metal ties, because there are many cases in which this would be inexpedient if not impracticable, since many Western roads must of necessity be built at as low a rate of first cost as possible; and as the construction of these roads (I refer here only to legitimate enterprises) is absolutely necessary for the development of certain districts, for the benefit of those districts, and incidentally for the benefit of the country at large, there are cases in which, for the present at least, wooden ties may be used and their use put under the head of "legitimate consumption." But there are other classes of railways: there are the roads which, having been cheaply built in the first place,

have built up the district they serve and are being improved to meet the requirements of increased traffic—on many of these roads metal ties might be laid to advantage; then there are the wealthy trunk lines, which instead of consuming great quantities of wooden ties every year for maintenance and renewals, should gradually introduce metal ties on their tracks; and finally there are the new roads in busy parts of the country, which are built in a first-class manner to accommodate a heavy traffic from the beginning—these lines should be laid with a metal track in the first place.

In these four ways the railway systems of the country might aid greatly in economizing the present supply of timber, but, in addition, they might help to restore the forests by establishing plantations and encouraging forestry. This has been done to a small extent, but the length of time necessary for the growth of a "crop" is a hinderance to any movement of this kind. In Pennsylvania, railways already have to go outside the State for their oak ties, and the mining industries in the once heavily timbered coal regions of the same State have to import the props, etc., for the workings. In Europe, steel is coming into extensive use for mines, both for props and beams, and for ties.

Some idea of the consumption of timber by railways may be gathered from the following particulars, which are abstracted from a Report on the Forest Condition of the Rocky Mountains (Department of Agriculture, Forestry Division, Bulletin No. 2), by Col. E. T. Ensign, forest commissioner of Colorado:

Union Pacific Railway.—During 1886 there were used in Idaho, Montana, Wyoming, and Colorado, 686,827 ties and 8,450,969 square feet of dimension timber.

Denver and Rio Grande Railway.—The following native timber was used in Colorado and New Mexico in 1886: 60,000 broad-gauge ties, 740,000 narrow-gauge ties, 3,000,000 feet, B. M., of dimension lumber. The approximate amount of timber required for annual renewals and repairs was 1,023,376 ties, and 5,625,000 feet, B. M., of sawed timber.

Colorado Midland Railway.—The number of ties for the construction of 250 miles of main track and the sidings, was estimated at 900,000, and the number of feet of timber for bridges and other construction work at between 6,000,000 and 7,000,000.

Atlantic and Pacific Railway.—During 1885 the consumption of native pine was 937,240 feet in New Mexico, and 2,028,959 feet, B. M., in Arizona. In 1886, 47,456 ties of native pine and 298,755 feet of native pine dimension lumber were used in New Mexico.

Another form of timber destruction, and one for which the railways are largely responsible, is that of fires; on many lines through tracts of timber there is abundant evidence of this fact in strips of charred stumps and logs along the track, sometimes spreading off into large patches. The spark arresters on many locomotives, especially on lines of minor importance, are very inefficient, and on some little lines in New England over which I have traveled, the wood-burning engines, although fitted with spark arresters, throw out continuous showers of sparks. Some interesting notes in respect to forest fires may be gathered from the reviews of the forestry interest in each State and Territory—given in the annual report of the Division of Forestry for 1887, by Mr. B. E. Fernow, Chief of the Division, which report, as well as other publications of the Division, I recommend for perusal to all persons interested in this important question of our timber supplies. In most cases there are laws and penalties relating to starting fires, etc., but the laws seem generally to be a dead letter; they are rarely enforced, and consequently little heed is paid to them. In New Jersey, the loss from fires for the last fifteen or twenty years is said to have averaged, on a low estimate, $1,000,000 a year, an amount which would nearly pay the entire taxes of the State. In Maryland, the loss by fires, "largely from locomotives," is estimated at between $30,000 and $40,000 a year. The total losses by fire form in the aggregate an enormous amount of timber, representing a wicked waste of material, and consequently of money. On the other hand, the steps taken towards planting are few and insignificant, being almost invariably on a very small scale.

Street railways, too, consume a great amount of timber, and it is probable that the ties, from their being covered up but not protected from moisture, have a short life compared with that of ordinary railway ties. When we reach that station of progress when we shall begin to follow the European precedent of building city railways of iron and concrete, we shall materially reduce one item of consumption of timber. But proper street construction must come before, or at least with, proper street railway construction.

In conclusion, the close relations of railways to the timber supply of the country have, I think, been clearly outlined in this paper, and I sincerely hope that at no distant time the railways will, in effect, cooperate with the Government in the conservation and protection of the timber resources, while at the same time they greatly improve the efficiency and value of their own works.

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U. S. DEPARTMENT OF AGRICULTURE.
FORESTRY DIVISION.
BULLETIN NO. 4.

REPORT

ON THE

Substitution of Metal for Wood in Railroad Ties.

BY

E. E. RUSSELL TRATMAN, C. E.

TOGETHER WITH A DISCUSSION ON

PRACTICABLE ECONOMIES IN THE USE OF WOOD FOR RAILWAY PURPOSES.

BY

B. E. FERNOW,
CHIEF OF FORESTRY DIVISION.

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LETTER OF SUBMITTAL.

FORESTRY DIVISION, DEPARTMENT OF AGRICULTURE,
Washington, D. C., March 10, 1890.

SIR: I have the honor herewith to submit a report on the use of metal as a substitute for wood in railroad ties, together with a brief discussion of other practicable economies in the use of wood material, this report being a sequel to Bulletins 1 and 3 of the Forestry Division, and forming a part of a continued investigation into the relation of railroads to forest supplies.

Respectfully,

B. E. FERNOW,
Chief of Forestry Division.

HON. J. M. RUSK,
Secretary.

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PLATE 21. Denham-Olpherts' Plate Ties (Indian State Railways; Denham-Olphert-Molesworth's Wedge Fastening (Indian State Railways).

PLATE 22. Indian State Railway Standard Tie.

PLATE 23. Denham-Olpherts' Plate Tie (East India Railway); Indian Midland Railway Bowls.

PLATE 24. Indian State Railway Tie (Indian State Railway); Northwestern Railway Bowls (Northwestern Railway).

PLATE 25. Indian State Railway Tie, double gauge (Bengal Nagpur Railway); MacLellan Bowl Tie (Calcutta Port Railway).

PLATE 26. Livesey's Bowl Tie (Buenos Ayres Southern Railway); Livesey's Bowl Tie (Central Argentine Railway).

PLATE 27. Hartford Tie (New York Central and Hudson River Railway).

PLATE 28. "Standard" Tie.

PLATE 29. Pennsylvania Railway Tie; Toncey's Tie (bowl).

PLATE 30. Ties: Cook & Hicks; International; Schofield's; Taylor's (bowl).

INTRODUCTORY.

It may seem superfluous to justify the publication by this Department of any new and useful information that has, directly or indirectly, a bearing upon the cultural conditions of the country; yet, since it might be questioned whether the investigations which form the principal subject matter of this report were germane to the work of the Forestry Division, a few words to establish this relation will not be considered out of place.

The value of the report on metal ties, as a compilation of hitherto unpublished and inaccessible or scattered information, will be self-evident and needs no argument to the engineer, for whose direct use and benefit it has been collated; but the indirect value to the country at large, and to the forestry interests especially, can only be realized by contemplating what effect the application of the information here presented may have upon our forest supplies.

Previous investigations by this division, notably those published in Bulletin I, 1887, have shown that the railroads of our country not only use a very large amount of forest supplies in their construction—probably not less than 20 per cent. of the total consumption of timber—but the material represented in this consumption is largely drawn from the thrifty young growth, the promise of the future, and thus the timber crop is utilized before it has reached the most profitable age and largest production per acre. More than that, the most durable and valuable timbers only are desired for this use, and, consequently, the forest areas which are culled of these valuable kinds must necessarily deteriorate in quality as regards their composition, the inferior kinds being left to dominate and exclude the more valuable kinds, which are placed at disadvantage by the unintelligent action of man in this culling process.

How much this is the case becomes apparent when we learn from reliable investigations that in the forests of Kentucky, where white oak represents 40 per cent of the natural growth, after it has been culled—mostly for railroad purposes—the new growth contains not more than 5 per cent. of this most valuable railroad timber.

The bulk of tie material is now largely cut from second growth, especially in the Eastern States, and young timber, from trees that will make only one tie, or at least only one tie from a cut, is called for by most specifications for ties.

This rapid and careless consumption of the best parts of the second growth can, of course, only be hurtful to the forestry interests of the future; we draw in this way upon the fund which we should hold in trust and allow to accumulate for the use of the next generation; worse, we do all we can to deteriorate the value of the investment by injuring its quality.

It has been shown repeatedly, all assertions to the contrary notwithstanding, that our annual consumption of wood products at present exceeds double the amount of wood material that can possibly reproduce itself annually on the area covered with wood growth. It is, therefore, of national interest and within the line of work of this Division to call attention to the necessity of husbanding timber supplies, and to furnish all and any information that may lead to a more economical use of these supplies or a substitution of other material where this is practicable. While such economy is desirable in all directions, it is especially so in regard to tie-timber, since, as has been stated, for this purpose the young promising crop of the future is utilized prematurely—and that of the best quality and of the most valuable timbers. Furthermore, it should be known that for those who furnish these supplies for the railroad companies there is but small, if any, profit in the trade. The ties are in most cases brought to the railroads by holders of small wood lots, and the price paid is hardly more than fair compensation for labor in making and hauling the ties, no value being placed upon the material itself. The substitution of metal for wood—even if this were effected readily and without delay—would therefore not result, as may be anticipated by some, in a loss to the owner of woodlands. He will only be prevented from killing the calf, as it were, before it is full-grown, while it has little or no value, and he is paid only for the slaughtering; in the end his crop, by being utilized later, will yield him proportionately more in quantity and value.

It has been suggested that railroads could be induced to substitute metal for wood only when it could be shown that an increase in the price of wooden ties is imminent. As will appear from an investigation recorded in this report, enabling us to compare conditions of the present tie market with those existing seven years ago, the price paid for ties in many localities is now even lower than it was formerly, notably in the northeastern States. Yet it would be a mistake to argue from this, as a general proposition, that more timber is in the country than before, that forest supplies are in excess of demand, and that prices are going to decrease continuously.

The law of supply and demand as affecting the price of this commodity is vitiated considerably by other conditions which influence the price. It is the excessive offer compared with the requirements, rather than excess of actual visible supplies available for the long run, that places the purchaser of this commodity in position to dictate the price, the offer coming from many holders of small parcels, who have no knowledge of general market conditions, and hence can not take advantage of a comparison between actual supplies in view and demand for the present and future in adjusting the price. The present temporary oversupply with low prices may be followed by a long-continued short supply and higher prices without any preconceived action on the part of those who market the supplies.

A timber crop, unlike an agricultural crop, is capable of being harvested at various stages of development. Timber fit for ties may be cut at any time, from the twenty-year-old sprout of the coppice to the old growth of the virgin forest, and the offer of the crop in this shape may be excessive at any time without necessarily indicating an overabundance of forest supplies in general and for the long run. The accidental simultaneous arrival at an age when the timber is fit for ties of a new growth over a large area may also in a given region make supplies appear plentiful if offered in that shape, and therefore for a time reduce the price; but this present oversupply and reduction of price must necessarily be at the expense of a future short supply and increase of price. Another reason for an apparent oversupply of tie timber may be found in the opening up of new sources of supply on such roads as are capable of extension, while the old roads, with no new fields, to enter, will necessarily experience a constant advance in prices with decreased offers, and will be the first to have recourse to metal on account of cheapness. These conditions are apparent from the replies received from various railroad managements, as recorded in the notes found in this report.

It should also be known that, within limits, a railroad management has it in its power—and this power is being used—to keep the price low by raising freight rates, so as to make the exportation of tie timber from its territory unprofitable. The condition of the tie market, then, can not be the only, or even the main, criterion as to when the time for substituting metal has arrived, even from a financial point of view.

But it is not a consideration of *initial* cost that makes the substitution of metal ties desirable and profitable. It is superiority of track, permanence of road-bed, safety, reduced cost of maintenance, and hence *ultimate* saving and economy, that recommend the metal tie, as will be seen from a study of the experiences in foreign countries here presented. It will be a matter of astonishment to our railroad engineers to find that almost 30,000 miles of railroad track lies on metal ties, which means over 15 per cent. of the railroad mileage of the world outside of the United states and Canada. The claim, then, that metal ties are an experiment and their general adoption premature for lack of experience, will have to be abandoned, as based simply on ignorance in regard to the real state of affairs.

The report, being primarily intended for the information of railway managers and engineers for the purpose of interesting them more directly in the introduction of a substitute for wood, is necessarily of a technical character; it is full of such details as alone can influence the judgment of the engineer. The laborious task which Mr. Tratman, without any adequate compensation, has performed in compiling the experience of the world in regard to this subject will, no doubt, be appreciated and the details welcomed by those most nearly concerned in it.

The general public will be interested only in the ultimate result, which bids fair to advance the use of more permanent types of railroad construction in the United States, insuring greater safety and speed of railroad travel.

The forestry interests of the country will be subserved by this report in a practical manner by spreading this information, which must lead to a reduction of the premature and illegitimate drain upon the forest resources of the future.

Perhaps an apology is due to the reader for the bulkiness of this report, which might possibly have been compressed into more compact form. The desire to make public as soon as possible the results of the investigation, and the fact that Mr. Tratman, leaving for Europe, could not devote more time to the literary form, must stand as an excuse for the deficiencies in that direction, which a carefully prepared index will also tend to alleviate.

That besides the adoption of metal ties there are other ways open to railroad managers for effecting desirable economies in the use of wood supplies has been pointed out at length in former publications of this division, and is again discussed more briefly in the present publication in connection with a canvass recently made in regard to consumption of timber supplies by railroads.

A curious lack of proper financial calculation has been noticeable in the writings of engineers when discussing the profitableness and making comparisons of the relative value on the balance sheet of various systems of construction. A railroad company that is bound by necessity to consider only the initial cost can, to be sure, always settle at once all financial questions by the limit of cash in hand; but few corporations are in such straitened circumstances, and the question constantly arises whether the temporary saving in initial cost is preferable to a greater initial expenditure which insures—either or both—decreased expenditure for maintenance and deferred expenditure for renewal.

This question is capable of solution by simple mathematical calculation, as will be shown further on in this report.

From such calculation it will appear, for instance, that a road using ties for which it pays 50 cents and which last eight years—like white oak, in many sections—can afford to pay $1.20 for a metal tie lasting thirty years (the presumed life of such ties) and be sure of saving at least the amount required for the renewals of the oak ties during thirty years; or, by doubling the life of the oak tie to sixteen years by means of preservative processes, we may pay 35 cents for such process and would still find an advantage on the balance sheet.

In conclusion, I may express the hope that the information here presented will not only be found of value and be welcome to railroad managers and engineers, but that its presentation from this office will bring them to a realization of their duty, as an intelligent and influential class of a great community with a future before it, to give thoughtful attention to the subject of forestry in general as one of the necessary economies in a modern civilized state.

Railroads, while the carriers of civilization, the promoters of development, have committed many sins for the benefit of the present at the expense of the future by needless forest devastation. Being institutions of a permanent character, it would seem that their managers ought to be interested in anything that pertains to judicious use of natural resources and to favorable cultural conditions, at least within the territory which their roads traverse. While with their large consumption of wood material they are directly concerned in the continuity of forest supplies, they must also be indirectly concerned in the prosperous development of their territory, and that proper use and recuperation of forest resources, proper disposition of forest and field areas are essential to continual development of prosperity should be recognized by them, and their influence to secure both should be brought to bear even were it only for their own selfish interest.

B. E. FERNOW.

NOTE EXPLANATORY TO REPRINT.—The opportunity has been taken by Mr. Tratman in this reprint to make slight alterations on pages 284 and 289, referring to the Brandwood tie, and to enlarge somewhat the list of errata to be found on page 58.

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CONSUMPTION OF FOREST SUPPLIES BY RAILROADS AND PRACTICABLE ECONOMY IN THEIR USE.

By B. E. Fernow,
Chief of Forestry Division.

The requirements of our railroad system in regard to forest supplies have been discussed several times in publications from this Division. A comprehensive canvass in regard to the kinds and quantities of timber used for railroad ties and their life was published in Volume IV of Forestry Reports, in 1884, and a more extensive discussion and computation of the consumption of forest supplies by railroads were given in Bulletin 1 from this Division. A canvass, made this year and tabulated below, was undertaken to verify some of the conclusions reached and to ascertain what, if any, the change in supplies has been during the last six years, as far as change in prices and personal views of managers might indicate. The tabulation by geographical sections will recommend itself to students of the subject as an improvement on the alphabetical one adopted by Dr. Hough in the first report mentioned, since forest and market conditions differ so widely in the various sections of the country that the relation of railroads to tie supplies can be profitably discussed only from local points of view.

The larger roads, mainly, have been canvassed as indicating the general and most prevailing practice. In the summary, the percentage of mileage to which the report refers compared with that in operation within the section is calculated, and upon that basis the amount of forest supplies consumed by the railroad system of the section is computed. Since the report refers to nearly 60 per cent.—ranging from 32 to 87 per cent. in the various sections—of the total mileage, such basis for computation will furnish a sufficiently close approximation to the truth for general discussion.

The consumption of ties goes for new construction and for renewals. Both these uses are, to be sure, exceedingly variable, the latter naturally being influenced by the increase of new mileage as well as by many other causes; only a general approximation, therefore, is possible. The present canvass places the number of ties needed for repairs at 60,000,000 per annum, the figure which Mr. Dudley estimated in the Bulletin I referred to, and somewhat lower than that figured in Mr. Kern's paper in the same publication.* To this, as has been there shown, 13,000,000 ties may be added for new construction, or in round numbers our present railroad system consumes 73,000,000 railroad ties, requiring at least 365,000,000 cubic feet of raw material. A rough computation of the proportion in which the various timbers participate in this consumption allows the following distribution of material:

Oak ties	45,000,000
Chestnut ties	3,500,000
Pine ties	12,500,000
Cedar ties (red, white, and California)	5,000,000
Hemlock and tamarack ties	2,500,000
Cypress ties	1,500,000
Redwood ties	2,500,000
Various	500,000

The oak, therefore, our most valuable timber, furnishes over 60 per cent. of the material, and not only from choice trees mostly, but from the young growth, which may make "one tie to the tree" or "one tie to the cut."

For bridge and trestle timber, etc., another 60,000,000 cubic feet of sawed material are to be added; so that a consumption of 500,000,000 cubic feet of wood. in the shape of forest-grown (round) timber for railroad purposes, which was claimed in a former publication, stands as a reasonable figure. This requires the annual culling of the best timber from probably more than 1,000,000 acres of our natural forest lands; and to furnish this amount continually not less than 10,000,000 to 15,000,000 acres of well-managed forest would be required, or in the absence of management—as at present—the area to be reserved for this purpose would have to exceed probably 50,000,000 acres, or more than 10 per cent. of our present forest area.

Since the railways are responsible for a very large amount of the consumption of timber, it must be one of the problems of a rational forest policy, in a country where forest management is not yet practiced, to encourage such economies in the use of timber as are within reasonable reach of railroad managers.

The use of wood and the method of using it are largely matters of custom everywhere. In the United States the enormous supplies which the native forest yielded have induced not only a very extensive but also a very wasteful use of wood, until now we have reached a point when the prospect of reduced supplies makes the study of economies a matter of national concern, and within a not too distant time private interest will also awaken to the need of it.

As a nation, with our present conception of private property rights, we have but little opportunity to check the wasteful use of our forest resources, except so far as this can be done by disseminating information which will lead to private economy. As far as the Government holdings of timber lands—still some 70,000,000 acres—are concerned, certainly a rational management is the need of the hour. The conditions in which this common property is left at present, even if considered merely from a business point of view, are deplorable. They are a disgrace to our nation.

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*As will be shown further on, this figure is probably over 30 per cent. below actual requirements, and a consumption of 80,000,000 ties for renewals nearer the truth.

In recognizing the necessity of Government action with regard to forest resources, the United States is the most backward of all civilized nations. Not only have all the European nations firmly established forest administrations, for at least that part of the woodlands held in the hands of the Government, but even Japan and China are inaugurating such, and the English colonies in India, Australia, and in Africa are fully imbued with this claim on Government supervision. Even in Canada the future action of the Government is at least not precluded, the Government retaining title to the land which is stripped of its timber, from which Canada, in fact, derives its principal revenue.

The consumption of timber for railway purposes includes ties, fences, telegraph poles, bridges, trestles and culverts, station-houses and other buildings, rolling stock, fuel. In all of these uses most companies would find it to their advantage to study economy.

Economy in the consumption of timber may be effected in two ways: (1) By the use of other materials as substitutes; (2) by employing means to increase the durability and life of the timber used.

The possibility of substituting metal for ties is fully discussed in Mr. Tratman's report and needs no discussion here.

While it can not be expected that the use of this substitute will be brought about by any consideration of the waning forest supplies, it is fortunate that the advantages, direct and indirect, which accrue from the use of metal ties are such as to recommend their employment; even before the time when the initial cost of the metal tie compares more favorably with that of the wooden tie and it's financial advantage becomes palpable.

Those roads which have a sufficiently permanent and sound financial status, to allow them to carry on their operations with a view to ultimate saving rather than to economy in first cost, and to consider reduction of maintenance expenses the financial aim of a well-managed railroad, may even now profitably adopt the higher priced metal tie.

The use of metal for the construction of rolling stock—not only car-frames and truck-frames, but of entire cars—has proved quite feasible and satisfactory. The economy to the railway company will consist in reduced cost of maintenance and repairs, and in longer life.

A mail car built entirely of steel, on a plan patented by Mr. Green, was put in actual service on the Louisville, New Albany and Chicago Railway (Monon route) some time in 1888, and Mr. Watkeys, the master mechanic of the road, informed me in September last that the car is still in use and has given satisfactory results. He stated that up to September 26 it had made about 88,000 miles, and had not cost anything for repairs. The cars on the experimental line of the Meigs Elevated Railway at Cambridge, Mass., are of metal throughout; the truck and floor frames are of iron and steel, and the body has transverse ribs or frames of metal tubes with sheet-metal panels. Freight cars with metal frames are already used quite largely.

The use of stone for buildings, and of stone and metal for bridges, trestles, and culverts, suggests itself, and the substitution of these materials for lumber is, in fact, gradually progressing on all lines that have acquired permanency. Yet this tendency does not seem to have made a very great impression when we find that even in New England and the middle group of roads—leaving out the Pennsylvania Railroad—from 3,500 to 4,450 feet B. M. of timber per mile is used, while Southern and Northwestern roads, which are expected to use more wood in construction, average hardly any more, and the more western roads, with fewer stations, and probably fewer water-crossings, use about 3,000 feet.

While bridges are being more or less replaced by stone and iron structures, wooden trestles even in permanent and well established roads continue the rule, and it is very questionable whether the accidents resulting every year from burning of wooden bridges and trestles or from their collapse and washing out are not more expensive to the railroad companies than better structures. Filling in to solid bank should be done as fast as possible, or at least preserved timber and paint should be employed in the construction of trestles. The substitution of iron and cement pipe for wooden culverts, or masonry and arches and abutments with iron roof or concrete, would also prove a final economy.

In regard to station-houses, freight-sheds, shops, round-houses, car-sheds, it is again the economy of maintenance which would dictate the use of stone or brick and iron sheeting. The use of paint at least should be insisted upon as long as wood is used. The objection that with increased needs it is cheaper to replace a small wooden structure by a larger one, is not valid when the design for the smaller structure is in the first place made with a view to enlargement and addition.

The use of wood for fuel can hardly be said to be objectionable and uneconomical, as far as forestry interests are concerned, if managed with proper discrimination. In fact, a very great waste in the American forest results from the fact that much of the inferior material can not be utilized for firewood, and remains in the woods to feed and make more destructive the recurring forest fires. Some two and a half to three million cords of wood are probably consumed for locomotive use. Wood-burning locomotives are still found in all sections where fuel supply from the forest is plentiful and coal expensive. The only objection that can be made to this use is that timber fit for better purposes is largely placed in the wood pile. Another objection, perhaps more easily avoided, is that wood-burning engines are more likely to set fire to the forests through which they pass; on such, therefore, more efficient spark-arresters than are used in many instances should be employed.

In passing, I may point out the superiority of live hedges along the tracks, where such protection is needed, in preference even to wire fences.

But, as we have seen, by all means the largest consumption and of the most valuable timber is that for railway ties.

There are various directions, besides the substitution of metal or other material, in which a more economical use of wood in this part of railroad construction can be and ought to be effected. Such economies consist:

(1) In using only the most durable timbers.
(2) In giving proper attention to the cutting and piling of ties before they are used.
(3) In paying attention to the drainage and ballast material of the road-bed.
(4) In replacing ties in the road-bed which have rotted from the attack of a specific fungus by ties of a kind not liable to attack by the same fungus, so as to avoid its spread.
(5) In boring spike holes and filling the old ones when re-spiking, and in the use of more permanent rail fastenings.
(6) In the use of tie-plates in order to reduce flange-cutting; and lastly,
(7) In the use of preserving processes to lengthen the life of the timber.

These economies, it must not be overlooked, have also a tendency to improve other conditions of railway management. They tend to effect greater permanency of road-bed and hence greater safety to life and rolling stock; for every improvement made in the track by lengthening the life of ties reduces the necessity for frequent disturbance of the road-bed, which is a well recognized advantage.

Duration or life of timber.—Comparative tests of the durability of various timbers have never been made, and the experiences of the practice give only conditional results, since a comparative account of conditions under which the timber is grown, handled, and placed, is rarely made. Not only do different species show varying durability, that is, resistance to decay, but the same species seems to exhibit a variation according to the locality where it is grown, and the part of the tree from which the wood is taken, and even its age seems to influence durability.

An attempt has been made to make the color of the heart-wood a criterion of the durability of the various timbers, and the following exhibit might tempt one to accept, at least partially, the propriety of such a standard.* That the sap-wood is less durable than the heart is of course well known.

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* See Dr. H. Mayr, "Die Waldungen von Nord Amerika, etc."

If we denote by *v. d.* = very durable, *d.* = durable, and *n.* = not durable timbers, we find:

Pronounced black, brown, or red heart.	Gray, light brown, light red, yellow heart.	White or slightly colored heart.
Lignum vitæ *v. d.*	Cucumber tree *n. d.*	Beech *n.*
Mesquit *v. d.*	Tulip tree *n. a.*	Birch *n.*
Catalpa *v. d.*	Black locust *v. d.*	Gum *n.*
Osage Orange *v. d.*	Coffee tree *d.*	Maple *n.*
Mulberry *v. d.*	Honey locust *d.*	Linden *n.*
Black walnut *v. d.*	Sassafras *d.*	Hemlock *n.*
California Cedar *v. d.*	Elm *d.*	Spruce *n.*
Red Cedar *v. d.*	Oak *d.*	Fir *n.*
Bald Cypress *v. d.*	Willow *n.*	Torreya *v. d.*
Redwood *v. d.*	Pine *d.*	Lawson's Cypress *v. d.*
Tamarack *v. d.*	White cedar *v. d.*	Port Orford Cedar *v. d.*
Douglas fir *d.*	Cypress (Cala.) *v. d.*	

The color of the heart-wood is due probably to the presence of tannin, which acts as an antiseptic, by making the albuminates in the sap insoluble; and since the most durable timbers seem to be those of southern localities, where therefore intense light and heat favor the formation of this antiseptic principle, it would also be reasonable to expect that trees grown in open stand would be more durable, and that the observed greater durability of second growth is due to the fact that it has grown up under full influence of sunlight.

The three timbers which without coloration of the heart show great durability are characterized by a strong smell, which leads to the presumption that ætheric oils take the place of the tannin and afford protection against attacks by fungus growth.

Some timbers, like the catalpa, begin soon to form heart-wood, while others, like the hickory, begin so late that but a small part of the trunk yields durable timber. This certainly is noteworthy in growing tie timber.

But the idea that the young wood is more durable because it is young, which seems to prevail among railway managers, must be considered erroneous. On the contrary, young wood, which contains a large amount of albuminates, the food of fungi, is more apt to decay, other things being equal, than the wood of older timber. Sound, mature, well-grown trees yield more durable timber than either young or very old trees. It is the rapid growth, exhibited in broad annual rings and due to favorable soil and light conditions, which yields the most durable timber in hard woods, and only as far as the growth in the virgin forest has been slow ought there to be a difference in favor of second-growth timber. In conifers, however, slow growth with narrow rings, which contain more of the dense summer wood in a given space, yields the better timber. The turpentine (pitch) accumulated in the summer wood of the conifers acts as a preservative by preventing the penetration of water and hindering the development and spread of fungus growth. Hence tapped trees on the tapped side where the pitch has concentrated itself—"light-wood"—is almost indestructible, while the rest of the tree, deprived of its turpentine, has lost its durability. In all cases within the same species, the heavier and denser wood is the most durable.

Coniferous woods, then, from comparatively poor soils, high altitudes and dense forest, and hard woods or deciduous, from rich, deep, warm soils and isolated positions, produce the most durable material.

Without means of determining the exact relative value of the different species, it is only possible to give the following enumeration, which, in general, proceeds from the most durable to the less durable ones:

EASTERN RANGE:

Conifers: Bald cypress (*Taxodium distichum*, Rich.); Red cedar (*Juniperus Virginiana*, L.); White cedar (*Chamæcyparis sphæroidea*, Spach.); Arborvitæ, White cedar (*Thuya occidentalis*, L.); Tamarack (*Larix Americana*, Michx.); Long-leaved pine (*Pinus palustris*, Miller); White pine (*Pinus Strobus*, L.); Red pine (*Pinus resinosa*, Ait.); Cuban pine (*Pinus Cubensis*, Griseb.); Short-leaved pine (*Pinus echinata*, Miller); Hemlock (*Tsuga Canadensis*, Carr.); Spruces (*Picea alba*, Link., *P. nigra*, Link.)

Broad-leaved trees: White oak (*Quercus alba*, L.); Post oak (*Quercus obtusiloba*, Michx.); Basket oak (*Quercus Michauxii*, Nutt.); Burr oak (*Quercus macrocarpa*, Michx.); Chestnut oak (*Quercus prinus*, L.); Live oak (*Quercus virens*, Ait.); Osage orange (*Maclura aurantiaca*, Nutt.); Hardy catalpa (*Catalpa speciosa*, Warder.); Black locust (*Robinia pseudacacia*, L.); Honey locust (*Gleditschia triacanthos*, L.); Red mulberry (*Morus rubra*, L.); Chestnut (*Castanea vulgaris*, var. *Americana*, A. DC.); Kentucky coffee tree (*Gymnocladus Canadensis*, Lam.); White elm (*Ulmus Americana*, L.); Slippery elm (*Ulmus fulva*, Michx.); White ash (*Fraxinus Americana*, L.); Black ash (*Fraxinus sambucifolia*, Lam.); Green ash (*Fraxinus viridis*, Michx.)

ROCKY MOUNTAIN REGION:

Mesquit (*Prosopis juliflora*, DC.), Red cedar (*Juniperus Virginiana*, L. and *J. pachyphlœa*, Torr.); Pinyon pine (*Pinus edulis*, Engelm.); Fox-tail pine (*Pinus aristata*, Murray); Douglas spruce (*Pseudotsuga Douglasii*, Carr.); Western larch (*Larix occidentalis*, Nutt.); Burr oak (*Quercus macrocarpa*, Michx.); Bull pine (*Pinus ponderosa*, Dougl.); Engelmann's spruce (*Picea Engelmanni*, Engelm.).

PACIFIC SLOPE:

Yew (*Taxus brevifolia*, Nutt.); Redwood (*Sequoia sempervirens*, Endlicher); Lawson's cypress (*Chamæcyparis Lawsoniana*, Parl.); Sitka cypress (*Chamæcyparis Nutkaensis*, Spach.); Canoe cedar (*Thuya gigantea*, Nutt.); White cedar (*Libocedrus decurrens*, Torr.); Douglas spruce (*Pseudotsuga Douglasii*, Carr.); Western larch (*Larix occidentalis*, Nutt.); Live oak (*Quercus chrysolepis*, Liebm.); Post oak (*Quercus Garryana*, Dougl.); Sugar pine (*Pinus Lambertiana*, Dougl.); Engelmann's spruce (*Picea Engelmanni*, Engelm.); Western hemlock (*Tsuga Mertensiana*, Carr.)

The *time of felling* has always been thought to influence the durability of timber. But while practical considerations will limit the choice of time, theoretically, with proper after-treatment no such influence can be admitted.

Early winter felling should have the preference, because, possibly, less fermentable sap is then in the trees; mainly, however, because the timber will season with less care, more slowly and more evenly, and before the temperature is warm enough for fermentation to set in.

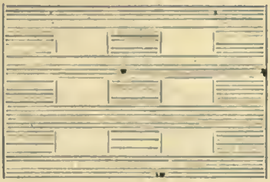
If the wood is cut "in the sap" it is more liable to fermentation and to the attacks of insects and more care is necessary in seasoning; for the rapid seasoning, due to the warm dry atmosphere, produces an outer seasoned coat which envelopes an unseasoned interior liable to decay. When cut in the leaf, as is done when the chestnut oak is cut for tanbark, it is advantageous to let the trees lie full length until the leaves are thoroughly withered (two or three weeks), before cutting to size. With conifers this is a good practice at any season, and if it can be done, all winter-felled trees should be left lying to leaf out in spring, by which most of the sap is worked out and evaporated, for it is the stored up albuminates, the fungus food, which are utilized in the budding and leafing.

After felling, further attention is needed to secure *thorough seasoning*. The idea expressed in some of the reports on the life of ties, that seasoning is of no consequence, contradicts all known facts. Under certain conditions of the roadbed this seasoning of the ties may satisfactorily progress while in place, but by so much as it is imperfect, by so much is danger from rot invited.

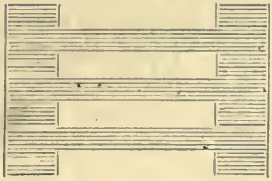
The experience of the Delaware and Hudson Canal Company, "that ties seasoned one year, being properly piled and the bark taken off, would last longer than ties used the same year they are cut and the bark left on," is sound and incontrovertible. Unfortunately no experiments are at hand to show the absolute money value of seasoning, because the length of time to which the life of ties is prolonged by seasoning is unknown.

That the careless piling of ties which is so often practiced costs the railroad companies thousands of dollars through the earlier deterioration of their roadbed, is quite certain. As proper piling does not mean extra cost, for it can be almost as easily done as not, it should be strictly insisted upon.

Most roads prescribe in their specifications for ties a method of piling, but this is done rather for convenience of inspection and loading than for securing proper seasoning. Piling, upon sound principles, is shown as the result of the specifications for the New York and New England, Pennsylvania, Lake Shore and Michigan, the Cleveland, Dayton and Columbus, Kansas City, Fort Scott and Gulf (which shows a diagram on its specification card), and a few other roads. The practice of these roads can be without difficulty and should be imitated by all others. The requirement is, to pile never more than fifty ties in a neat square pile, in such a manner that one tier contains six to nine ties, separated from each other by a space equal to about the width of the tie, the next tier consisting of one tie placed crosswise at each end of the first tier. The bottom tier should consist of two ties, or better, poles, to raise the pile from the ground. The piles to be 5 feet apart. The end view of the pile thus:



The side view thus:



In this manner a better result at least will be obtained than by the indiscriminate close tumbling together of the ties, so often practiced.

If possible, the piling ground should be somewhere in the woods, or at least away from the sun, wind, or rain, so as to secure a slow and uniform seasoning.

If dried too rapidly, the wood warps and splits, the cracks collect water, and the timber is then easily attacked and destroyed by rot.

The best method of obtaining proper seasoning, in a shorter time, without costly apparatus, is to immerse the prepared timber in water, from one to three weeks, in order to dissolve and leach out the fermentable matter nearest the surface. This is best done in running water—if such is not at hand, a tank may be substituted, the water of which needs, however, frequent change. Timber so treated, like raft timber, will season more quickly and is known to be more durable.

If practicable, the application of boiling water or steam is advantageous in leaching out the sap.

The Atchison, Topeka and Santa Fé road has made the experiment of leaching pine ties for two months, with the result of increasing their durability to a considerable extent (time not stated). It also reports that pine ties cut in summer and placed in track while green last three years; if cut in winter and seasoned before use, they last about five years; if cut in winter and water seasoned, they will last five and one-half years.

In the canvass made in 1883 the question was asked, whether ties were preferred from old or young growth, and whether hewn or sawed. While in the majority of cases the answer runs "hewn, and one tie to the cut, from small trees" or even "one tie to the tree," there are others who see no difference in the durability of sawn or hewn, some even preferring the former, especially with coniferous woods and when all heart can be secured.

Some give as reasons for their preference for young timber, that old timber is more liable to check, or more difficult to work "being tougher," or, and this is the most likely reason for observed inferiority, because poorer timber is furnished in sawed ties, namely, such as is not good enough for other purposes. Some use sawed ties because they can be had more cheaply—probably where other roads insist on hewn ties; others use hewn ties because they can be had more cheaply—probably where saw timber is scarce and coppice growth plenty.

It has been stated before that there is not necessarily any superiority to be found in young growth; on the contrary, well-grown mature trees furnish more durable timber. In fact, the young timber of conifers is invariably poor, especially if quickly grown, and the young timber from the dense hard-wood forest, where it grows slowly, is also poor. It is, therefore, an inexcusable waste and folly to insist indiscriminately upon ties cut from trees that will make but one tie or that the cut should make but one tie. The excuse for it can be found only in the fact that hewn ties do seem to last longer under otherwise unfavorable conditions and can be furnished only from such timber. It is claimed by some roads that hewn ties will last 30 per cent., or from one to three years, longer that sawn. The reason is obvious. The sawn face is more or less rough and collects water, and thus gives opportunity for fungus growth, while the smoother face of the hewn tie sheds the water. With hard woods of good growth, careful manufacture, proper seasoning, and with well-drained road-bed, the advantage of the hewn tie would probably not be equal to the enormous waste of wood necessary in its manufacture.

Some of the reports of those roads which make no difference between sawn and hewn ties, or which prefer the former, are worthy of note.

The Grand Trunk Railway desires that a tree should average four ties, and says "it matters not whether they be hewn or sawn, so long as the upper and lower faces are flat and the sides uncut. Oak ties are taken when sawn on four faces, but no other kind." The ties used by the road—oak, tamarack, hemlock, and cedar—average six to seven years in duration.

The Detroit, Lansing and Northern Railroad, using oak with a life of eight and hemlock with a life of five years, finds no difference between hewn and sawed ties, "if made of similar timber."

The Kansas City, Fort Scott and Gulf Railroad, using oak with a life of eight years, says: "If made from large timber, no preference is had between ties that are sawn and those that are hewn. Large timber is deemed best."

The preference is given to sawn ties, and from large trees, by the Oregon and California Railroad, using red fir of eight years life; by the Bangor and Piscataquis Railroad, with cedar of fourteen and tamarack of seven years' duration (put in track when half seasoned, although full seasoning is recognized as preferable); by the Mobile and Northwestern Railroad in Mississippi, "if all heart can be obtained and large timber, as it has less sap-wood. The small trees along the line of road do not make as good ties as the large timber."

The Arkansas Midland Railroad prefers sawed ties, although they are more costly. "Cypress ties should only be sawed from large trees, post oak and white oak ties from small trees are equally as good as from large ones."

The Alabama Great Southern makes a point that the ties should "not be cut through the heart of the tree," the philosophy of which is, probably, that the long-leaf pine ties are liable to have the heart break out and sliver. The significant statement is also made that the oak from the south end of the road is not as durable as that from the mountains on the north end. The difference is probably due to track conditions rather than to locality of growth.

Durability or life of ties.—The life of timber in use as ties is reduced by two causes, namely, a mechanical one, the breaking of the wood fiber by the flange of the rail and by the spikes, and a chemical or physiological one, the rot or decay which is due to fungus growth. These causes work either in combination or, more rarely, independently. A soft wood may be easily cut into and made useless before rot takes place—as, for instance, in the case of such otherwise durable woods as redwood, chestnut, etc., but the breaking of the fibre in most cases is only the antecedent and forms part of the favorable conditions for the fungus growth—other timbers may be attacked by rot first, which, of course, is followed soon by a breaking of the fiber.

The exterior conditions favorable to decay have been discussed at length in Bulletin 1; the controllable ones consist mainly in the drainage conditions of the road-bed. Rock ballast is best drained, and hence the best record comes from such road-beds; gravel is next best and clay or loam is about the worst; on the other hand, where soft-wood ties, like chestnut, are used, the hard rock ballast, while unfavorable to decay, reduces their life by pounding and cutting. Sand ballast seems to vary considerably; a sharp, coarse silicious (not calcareous) sand with good under-drainage should be next best to gravel, while some reports give a heavy black soil and loam as better than sand. The reason why sand, although offering good drainage, is favorable to decay, may be sought in its great capacity for heat, which induces fermentation.

In Louisiana "ties on black loamy soil rot out in one-third the time of those laid in a clay soil. Ties exposed to the sun all day rot out in less time than those which are shaded a part of the day. Shade and a free circulation of air are requisite to the best lasting of any timber in our climate."

From fifteen years' experience on the Cumberland and Pennsylvania Railroad it is stated that ties supported in stone ballast have 20 per cent. longer life, as far as rot is concerned. The Eastern Kentucky Railroad claims that with slag ballast oak ties will last two years longer than in sand, while on the Cleveland, Columbus, Cinncinnati, and Indianapolis Railway such ties were found to last two years less in slag ballast than in gravel. The nature of the slag, it should not be forgotten, is very varying, and hence its value for ballast. The East Tennessee, Virginia and Georgia Railroad allows in rock ballast eighteen months longer life than in a soil bed, and notes in sandy soil the most rapid decay.

Experience on the Hannibal and St. Joseph Railroad ranges the various kinds of ballast as follows: stone ballast best; next, coarse gravel; next, soil, and worst, cinder and sand ballast.

The New York, New Haven and Hartford Railroad, six years ago, ballasted its road with broken stone to a depth of 14 inches; stone of not more than 2 inches in size was used, and at the rate of 4,000 cubic yards to the mile. It was expected that ties in such a road bed would last two years longer than in gravel ballast. Yet now it is found that, with the heavy traffic, the high rate of speed, and weight of engines and trains and the use of chestnut ties, these do not last more than five years, the cutting of the rail on the upper and of the stone on the lower side wearing the ties rapidly.

Even the oak tie will succumb to the pounding it receives from such ballast, as the report of the Erie Railroad shows, which, while admitting that ties are less liable to decay in broken stone ballast, finds this ballast "on the heavily used portions of the line hard on the ties, by cutting, so that the oak ties are worn out before they rot."

Thus the life of ties of the same timber varies considerably, not only according to climate, and character of the timber, and the treatment the ties receive before being laid, but also according to the character of the road-bed and the traffic. From the reports of the 283 companies in 1883—which, by the-by, are now so consolidated that the 85 companies reporting to this year's inquiry represent almost 50 per cent. more mileage than the former 283—the following tabulation has been made, showing the range and average duration of ties of various timbers under present usage. The aim of well-managed roads, of course, should be so to combine conditions of road-bed, inspection, and handling of ties, that the highest average duration at least should be obtained.

The long life given to honey locust in the table on page 25 is probably due to a misnomer, black locust being meant, as honey locust is probably not a very lasting timber. The duration of mesquite, if sound, is claimed to be interminable.

Kind.	Range.	Average.
Conifers:		
Redwood	8–15	11–12
Bald cypress	4–12	8–10
Red cedar	....	10
Tamarack	4–12	7–8
White cedar	4–10	7
Pine, long-leaf	5–10	6–7
Pine, red and white	4–8	6
Pine, bull (California)	6–9	6–7
Pine, bull (Colorado)	3–6	5
Hemlock	2–8	4–6
Spruce	3–7	5
Broad-leaved trees:		
White oaks	3–12	7–8
Chestnut	4–12	7–8
Honey locust	....	10
Coffee tree	7–10	....
Cherry, black walnut, locust, sassafras	6–10	7
Mulberry	5–6	6
Mesquite	....	....
Elm	4–9	6–7
Black oaks	2–7	4–5
Ash, beech, maple	2–7	4

The suggestion of Mr P. H. Dudley (see Bulletin I), that ties which are attacked by a specific fungus in a given locality be replaced by ties of a different species not so attacked, in order to get rid of the infection, is worthy of consideration.

The necessity of employing an expert to determine the fungus causing the rot and to designate what kind of timber to substitute in order to avoid the specific fungus, would probably form the practical objection to this expedient.

METAL TIE-PLATES AND METHODS OF FASTENING.

The experience that the more durable timbers can not be utilized to the full length of their life, because of the flange cutting which destroys them mechanically, suggests at once the use of metal tie- or bed-plates or other means for reducing this mechanical destruction. Such bed-plates correspond to the rail chairs in use on English roads, but are less expensive. Some time ago the use of a hard-wood plate, let into a soft-wood tie under the rail-foot, was proposed, but the advantage thus gained was probably not proportioned to the labor of inserting the plate, for it seems not to have found wide application.

The use of a sheet of felt, one-quarter of an inch thick, placed between tie and rail, has been found quite satisfactory in France with preserved ties in preventing flange cutting, the felt lasting five to ten years. The experiment of the Baltimore and Ohio Railroad of using lead, sunk into the wood, is well known. Though effective to some extent the expense was too great. The method of fastening the rail to the tie has also much to do with the wear of the tie.

That the wear from spiking and frequent respiking must needs reduce the life of the tie is obvious; not only is the fiber destroyed mechanically, but water collects in the old spike holes and induces rot, while the loosening of the spike and consequently of the rail produces a vertical pounding which accelerates the wear of the rail-foot into the tie.

That by boring spike holes before the spike is driven the adhesion of the spike is increased, the track kept longer in safe condition, the wear under the rail-foot reduced, and the tie made to last longer has been shown in Bulletin 1, where experiments in this direction are recited at length. The filling of the old spike holes with wooden plugs to reduce the liability to rot was reported as satisfactory practice by the careful manager of the Cleveland, Mount Vernon and Delaware Railroad, who used plugs ½ by ½ by 5 inches in size. The New York, Pennsylvania and Ohio road also uses such plugs.

The common spike, now almost exclusively in use, must be considered the poorest and most unsatisfactory part of our railroad construction. Not only is a large part of the reduction in the life of railroad ties to be charged to these imperfect fastenings, but they are probably responsible for more damage to rails and rolling-stock, and for more accidents than is generally recognized. An improvement, therefore, in rail-fastenings is decidedly needed.

Various changes in the shape of the spikes have been made, which do not, however, appear to increase the efficiency of an ordinary well-made spike; tests at the St. Louis bridge having shown that ragging and curving even reduce the efficiency below that of the ordinary spikes.

The most promising improvement in spike-fastenings is, perhaps, the Davies locking spike, recently come into use, which seemingly obviates some of the objections to which all spike fastenings are exposed.

Its sharp cutting edges reduce the dangers from mechanical destruction of the wood-fibre; and as it runs diagonally across the fibre ($\overline{\diagdown}$) it will undoubtedly hold more firmly than the straight spike, and thus, by keeping rail and tie closely connected and diminishing the necessity of frequent respiking, will necessarily save the tie from premature destruction.

The use of wood screws with washers or screw-bolts would of course be superior in every respect to the present spike fastenings, and this change alone in the fastening material would make ties last considerably longer, besides insuring greater safety. Such screw fastenings, of various designs, with holes bored to receive them, are now largely used in Europe. In this country the Bush interlocking bolts have been employed with good results by the New York Central and Pennsylvania railways. Another screw fastening of simple construction is designed and used by Mr. M. W. Thomson, engineer of maintenance of way, Pennsylvania Railroad. The only objection to the use of such fastenings is their greater cost, increased labor, and need of skilled labor in their use. But after all, the use of bed-plates in connection with proper fastenings alone can satisfy present requirements of track where heavy traffic on wooden ties with flange rails is to be safe.

The experience with bed-plates in Germany shows that after the plate has adjusted itself to the tie, which requires some time and some cutting into the wood, "the line which was employed for seven years for the purpose of determining this wear, gave hardly any wear to the ties protected by plates; in every case showing less than 1 millimeter loss per year," while that of oak ties, unprotected, was nearly four times as large (one-fifth inch).

Other roads, where bed-plates are used, report considerable increase of life not only of spruce ties on the tangent, but also of oak ties which were used on the curves, giving in such position the oak ties 16.6 and the spruce ties (treated) 16.7 years' life, a very remarkable service.

Bed-plates are to serve the following objects:

(1) A more even distribution of rail pressure over a greater area of the tie, and thereby
(2) Retardation of the mechanical destruction of the tie by cutting, and
(3) Less danger of tilting of rails;
(4) To prevent the lateral bending of spikes or screws and thereby loosening of rail;
(5) To increase resistance of screws and spikes against lateral motion or spreading of rails.

To attain these objects the following conditions in the form of the plate are necessary:

(1) It should be sufficiently large to increase sensibly the bearing surface upon the tie. A length of 5½ inches and a width of 4½ inches in addition to the width of the rail-foot, or altogether 8½ to 9 inches are considered minimum dimensions.
(2) It should be sufficiently thick to take up all pressures without effect on the shape of the plate; the minimum thickness is given as one-half inch.
(3) It should be so placed that the larger bearing surface be on the inside of the rail where the pressure is greatest and resistance therefore most needed, so that 2½ inches lie inside and 2 inches outside the rails.
(4) It should increase the resistance of spikes or bolts against lateral pressure, by projecting shoulders against which the fastenings bear.
(5) It should relieve the fastenings from lateral pressures by having the rail-foot rest directly against projecting shoulders.
(6) It should be secured against lateral motion upon the ties by having the lower surface provided with short sharp ridges (not deeper than three-sixteenths to one-fourth inch, three being used, the inner tooth-rim deeper than the outer), or other contrivances which increase the friction between plate and wood.

After considerable experience with other forms, a bed-plate answering all these requirements has been designed and used by Mr. Post, the well known railroad engineer of the Netherlands Railway. The gradual development of the ideal bed-plate is described by him in Glaser's "Annalen für Gewerbe und Bauwesen," 1887, and the first and ultimate forms are shown in accompanying cuts.

He remarks in regard to results:

(1) After 100 to 500 trains the ridges have sunk into the oak ties; knots must be avoided under the bed-plate.

(2) After twenty months the impressions of the ridges were found sharply cut and the edges unbattered.

(3) The gauge was kept almost as well as with metal ties, *i. e.*, better than with oak ties without plates.

(4) The fastenings showed neither wear nor loss of shape nor loosening.

On the Prussian railways, instead of the parallel sharp ridges a network of diagonally crossing ribs is cast on the under surface of the plate, which reduces expense and has been found entirely satisfactory and fully answering the purpose of close adjustment between tie and plate.

In the United States and Canada several roads, among which the Intercolonial, Atlantic and Pacific, and Maine Central, have begun the use more or less extensively of a bed-plate weighing 2 pounds, which consists of a simple steel channel 8 inches long, 3⅜ inches wide, 3-16 inch thick, and with flanges turned down on the long sides ⅝ inch deep, which are driven into the tie parallel with the fiber, two spike holes having previously been punched into the plate. While these plates are certainly exceedingly simple and easy of application, they can not, of course, satisfy all the requirements demanded above; their bearing surface is rather small and the metal thin; there is also the objection that the flanges open new grooves for water to penetrate and collect in, thus presenting favorable conditions for the rot, which is not the case in the above described forms.

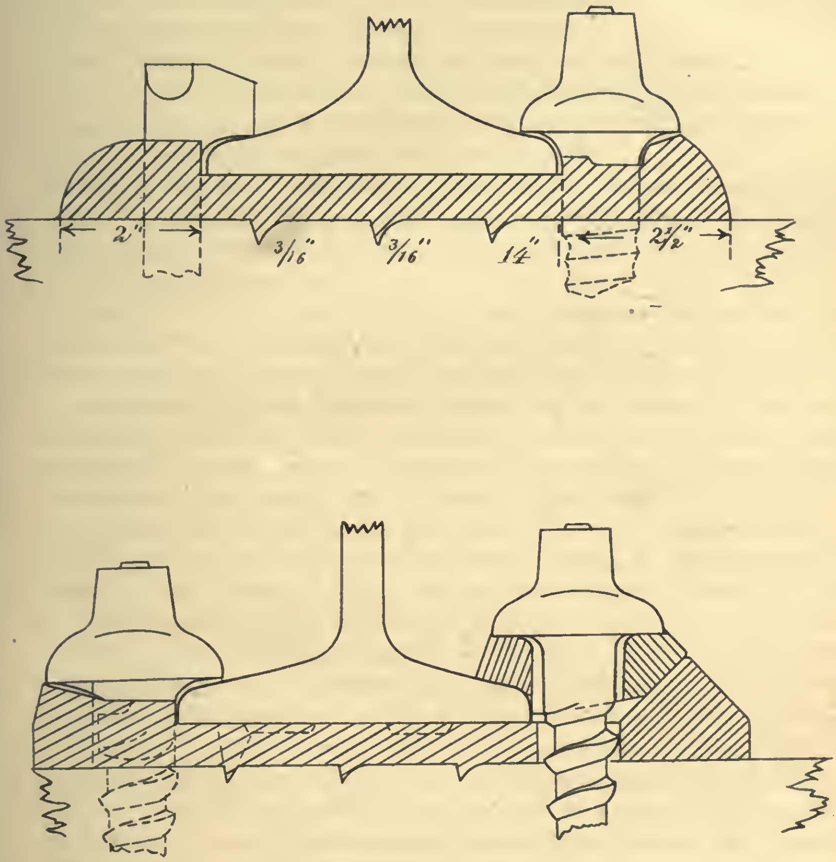
In regard to the brief experience had with this plate, the chief engineer of the Intercolonial Railroad says:

> The Servis tie-plate does very good service on cedar ties and at joints, but does not appear of sufficient strength, as now manufactured, to resist the heavy traffic passing over them, as we have found they very soon become hollow backed.

Mr. L. B. Robinson, manager of the Atlantic and Pacific Railroad Company, western division, makes the following statement:

> We bought about 70,000 of these bed-plates last year for an extension of our line, which will, however, not be opened until next month (May), so that we had but little experience with these plates.
>
> About a year ago I put a few of these plates under rails on our main line. The rails were light weight, 50 pounds to the yard; the ties were California redwood, which is a soft timber. We are using on this division engines weighing sixty tons. The few plates that we put there have made a very fair showing. Without the plates the rails in the same locality have sunk into the tie from one-half to one and one-half inches, while rails resting on the bed-plates are simply even with the top of the tie; in a very few instances they have sunk into the tie, say one-eighth of an inch. The plates are of too small an area, in my judgment, for such soft timber as California redwood. If they had been made an inch and a half longer and an inch wider I think much better results would have been obtained.
>
> As soon as our extension, noted above, is opened, these plates will be subjected to heavy traffic, and in the course of the next six months I may be able to give you more definite information.

The manager of the Maine Central Railroad, using principally cedar



POST'S TIE BED PLATE

ties, expresses his entire satisfaction with the use of the Servis plate, and says:

> Their use has so thoroughly demonstrated their great benefit, not only as a bed plate but also as a rail brace, keeping the track from spreading, that they now receive the hearty commendation of all our trackmen.

From these remarks we may infer that the bed-plate, like all other parts of railroad construction, must be adjusted to the special conditions of track and traffic. What is satisfactory and sufficient in one case may not be so under changed conditions.

The Perkins tie-plate, resting on a thin wooden block placed on the tie avoids the cutting into the tie by the rail flanges, but, besides other disadvantages, is apt to reduce the efficiency of the fastenings, thereby failing in one important office of the ideal plate.

Other bed-plates which strive to meet more of the requirements made by Mr. Post, as stated above, are the Thomson (Pennsylvania Railway), the Cox (McConway and Tooley), the Wrenshall, the Sandberg, and the Stuart elastic plates.*

Lately a "shoulder tie-plate" has been placed on trial on the Pennsylvania lines. This plate, weighing 4 pounds, is stamped out of one quarter-inch steel plate, 12 inches in length and 5 inches in width, thus giving about three times as much bearing surface as the rail, while along the rail-foot on both sides a shoulder of about one-eighth-inch depth is raised in the process of stamping, which helps to keep the spikes from wearing at the neck and to preserve the gauge.

It is asserted that the use of bed-plates will increase the wear of rails. This is conceivable under two conditions, namely, if the fastenings are imperfect and loose, allowing the pounding of the rail upon the plate, or if the bearing surface is enlarged beyond proper limits, counteracting the elastic features of the tie, especially upon an unelastic ballast (stone). Here, as everywhere in railroad construction, the relation of each part to the other and to the service required must be kept in view.

Even the use of a properly constructed splice-bar, like the "Samson," must be counted among the means of economizing in the life of ties.

Preserving processes.—With the adoption of means which secure the tie against mechanical destruction the question of preserving it against rot assumes at once a new aspect.

While in France not a tie is laid without subjecting it to a preserving process, and while the same practice prevails largely in England and in Europe generally, but little has been done in this direction in the United States.

The reasons for this neglect are various, mainly the cheapness of tie timber and the expense of preservative processes, and further the observation that flange cutting proceeds often more rapidly than rotting. Uncertainty in regard to the efficacy of various processes, unsatisfactory experience with processes improperly applied, and unwillingness to spend on initial cost for the sake of a future saving may also have had something to do in retarding the introduction of preserving processes.

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* See, in this connection, Mr. Russell Tratman's paper on "The Improvement of Railway and Street Railway Track," in Transactions of the American Society of Civil Engineers, March, 1890. The Holgate tie-plate, with lugs instead of shoulders, in successful use on the Grand Trunk Railway, came too late to our notice to be noticed in the text.

In railroad building there is such an intimate and mutual relation of the different parts of construction that no one can be determined upon without keeping in view all the others. As we have seen, the use of rock ballast, which promised by its effectual draining a longer life to the chestnut tie, by its hard pounding destroyed it sooner than it would have been destroyed by rot in a gravel or dirt ballast. So, too, preserving processes which soften the wood fiber, as some are apt to do, while preventing rot would reduce the life of the tie through mechanical action, while a process that hardens the wood, as claimed for the burnettizing, might make even a soft tie last as long as an untreated hard-wood tie. But the combination of bed-plates with preserving processes promises to make almost as satisfactory and perhaps as economical and safe a track as one on metal ties.

The various processes, their value and their cost, have been at length and admirably set forth in a pamphlet by the Society of Civil Engineers and in more condensed form in a report by Col. Henry Flad, civil engineer, contributed to Bulletin 1 of this division. Some new processes have come into use since the preparation of that report; but as the value of such processes can only be determined by years of experimental use, the discussion of these is left to some future time.

I should, however, mention one new process quite at variance with the conceptions upon which all processes have hitherto been based. While those processes attempt to eliminate the sap of the wood and substitute in part, at least, an antiseptic, which is to keep out moisture and make the germination of fungi impossible, "vulcanizing" is carried on upon the claim that by pressure and heat such changes in the chemical constitution of the sap can be produced as to make it incapable henceforth of sustaining a fungus growth. While the argument upon which the effect is claimed in the pamphlet of the New York Vulcanizing Company is open to criticism and stands upon a rather uncertain physiological basis, it is not impossible nor improbable that the claimed change in the chemical constitution of the sap is produced, but whether, under the influence of atmospheric agencies, bacteria, and fungus spores this change will remain permanent and the fungus growth be prevented remains still to be seen. It is claimed that the teredo has not attacked vulcanized wood; but this fact does not argue immunity from attacks by fungi.

According to a statement of Mr. F. K. Hain, manager of the elevated railroad lines in New York, "yellow pine timbers treated by this process have been in use on the road for the past six years, without showing any rot and hardly any wear by cutting, where untreated timber rapidly decayed. Most of the timber now in use by this company has been treated by this process, and all renewals are made with vulcanized timber." From an analysis of vulcanized oak, made by Dr. C. F. Chandler, it appears that the formation of antiseptics during the process has really taken place in the wood, the analysis showing altogether 11.90 per cent. of such materials, namely, 0.36 per cent. neutral oils, turpines, etc.; 0.77 per cent. phenols, and 10.78 per cent. resinous acids.

The process consists simply in subjecting unseasoned wood to dry air, heated to from 400 to 600 degrees F., under pressure of 100 to 175 pounds per square inch, heat and pressure being regulated according to the nature of the timber and the result to be obtained.

The fiber of the wood seems to be hardened, and the color can be kept natural or changed at will.

Altogether, this process is among the most promising of the many designed to lengthen the life of timber. Its advantages, besides simplicity and cheapness—the present charge is $8 per thousand feet B. M., which would bring the cost per tie to 3 cents—are, that unseasoned timber is preferably used, that the fiber is not weakened, that the timber may be worked after treatment without exposing any untreated part, for it seems treated through and through, that it seems unaffected by atmospheric changes, being thoroughly seasoned by the process.

A few notes on the status and experience of tie preserving in this country which have come to the writer's notice may find insertion here.

Heavy oil of tar, commonly called creosote (either from wood-tar or coal-tar), and chloride of zinc are the most commonly employed materials in this country.

The Chicago Tie Preserving Company, at its own works (which supply ties for the Chicago, Rock Island and Pacific Railway under contract) and at the works erected by it at Laramie, Wyo., for the Union Pacific Railway, and at Las Vegas, N. Mex., for the Atchison, Topeka and Santa Fé Railway, uses the zinc tannin process; the Southern Pacific Railway has both creosote and zinc plants at its Houston works; the Creosote Lumber Construction Company, of Fernandina, Fla., and the Carolina Oil and Creosote Company, of Wilmington, N. C., use the wood creosote oil; the Lehigh Valley Creosoting Company, of Perth Amboy, N. J., Eppinger & Russell, of New York, and the Old Dominion Creosoting Works, of Norfolk, Va., use dead oil of coal-tar; the Louisville and Nashville Railway has a creosoting plant of its own, used for piles and timber; the Boston and Maine Railway has a kyanizing (corrosive sublimate) plant at Portsmouth, N. H., which has been used for treating hemlock ties.

The Louisville and Nashville Railway's creosoting works, situated at West Pascagoula, have for ten years creosoted piles to protect them against the teredo, also bridge and trestle timber, but have never creosoted ties, because it is believed that with ties at 23 to 30 cents apiece the additional expense would not be justifiable. The chief engineer writes that the cost of creosoting them would be about $24 per 1,000 feet board measure, or $1 per tie, including creosoting, freight, and handling, assuming that they take 1½ gallons of oil per cubic foot.

This reasoning is not quite fair, since ties would not, or need not, take up more than one-third of the material stated, and are probably more cheaply handled than bridge and trestle timber. The cost without transportation is stated at 25 cents per tie by Colonel Flad. Creosoting is, no doubt, the most expensive process, and as it is said to soften the timber may not even be found as desirable for tie preserving as a process using metal salts.

Mr. F. C. Prindle, of the Carolina Oil and Creosote Company, Wilmington, N. C., writes as follows:

> We are now using only our heavy wood creosote oil for creosoting purposes. I suspect that the chief difficulty in introducing creosoted ties in this country lies in the fact of their considerable first cost, and the prevailing policy with new roads seems to be to build as cheaply as possible at the outset and then each succeeding administration is much inclined to keep the yearly repairs of roadway down to the minimum, and the long-run policy of building permanently at first and with very much smaller repair bills afterward seems to be ignored. The approximate increase in cost of a creosoted over a plain tie is about $14 per 1,000 feet board measure when creosoted with 10 pounds of oil per cubic foot and $16 when creosoted with 12 pounds of oil per cubic foot, or about 60 cents per tie.

The Newport News and Mississippi Valley Railway had thirty pine ties creosoted with dead oil of coal-tar at the Old Dominion Creosoting Works, Norfolk, Va., some years ago; one was taken up in July, 1887, after five years' service, and was reported to be in good condition and likely to last for fifteen years more. The ties were in track under heavy traffic, but the spikes maintained a firm hold. Mr. S. D. Puller, manager of the works, states that prices range from 75 to 85 cents per tie at the works. Mr. George S. Valentris, manager of the Eppinger & Russell Creosoting Works, New York, states that ties treated with dead oil of coal-tar have given satisfactory results, but that the first cost keeps them from being generally used; the cost is from 90 cents to $1 for a tie 8 inches by 6 inches and 8 feet length.

The Atlantic Coast Line put down some creosoted pine ties three years ago, the process costing $10 per M feet, B. M., or 12 cents per cubic foot, which would bring the cost per tie to a little over 40 cents.

The Savannah, Florida and Western Railroad Company creosotes yellow pine piling and bridge timber at $12 per M feet, B. M.

The Boston and Maine Railroad Company for eight years used hemlock ties kyanized, with bichloride of mercury, at 10 cents per tie, with satisfactory results, but when hemlock ties increased in price, and cedar ties, lasting eight years, became cheap (33 cents), no advantage seemed to accrue from the use of the process and it was abandoned.

Even if we allow the cost of the hemlock tie at 35 cents, if by the process it can be made to last twelve years, which seems not unreasonable to expect, it would be cheaper than the cedar ties, since the annual charges together with cost of renewal compare as 5.98 to 5.67 cents in favor of the preserved hemlock tie.

The average cost of treatment by the zinc process (burnettizing) is placed at 20 cents by the Chicago Tie Preserving Company.

The Chicago, Rock Island and Pacific Railroad has had such ties in use for the last four years, expecting them to last sixteen years. The manager of the road writes as follows:

> The life of an ordinary hemlock tie is three years; the life of a hemlock tie burnettized is sixteen years, twice as great as the life of an oak tie. We would use hemlock ties entirely, treated in this manner, if the facilities for burnettizing were sufficient to meet the requirements; and it is probable that in contracts to be made in the future we shall demand increased facilities and to an extent to meet all necessities, in which event we would, of course, use no oak ties at all. The hemlock tie costs 25 cents and the cost of burnettizing is 20 cents, making the total cost 45 cents, which is also the cost of an oak tie.

The Atchison, Topeka and Santa Fé Railroad Company kindly furnishes the following statement in regard to the cost of burnettizing with the Wellhouse process at Las Vegas:

	Cents.
For chemicals	11.7
For labor	4.3
For fuel	.6
	16.6

This is almost 50 per cent. higher than the figures of Colonel Flad.

Mr. A. A. Robinson, general manager, under date November 21, 1889, adds:

> The indications thus far are favorable and satisfactory. In 1885 we placed 305 of these treated pine ties in the main track just north of the bridge over the Kansas River in North Topeka. A few weeks since I examined these ties and found no evidence of decay, each tie being apparently as sound as a dollar.

Since oak ties last year on that road cost 48 cents free on board at Kansas City (a low price), and the pine ties 34 cents in New Mexico, the oak lasting seven and a half years, the treated pine, even if we increase its price to 60 cents, would need to last only ten years and yet be cheaper. Experience with burnettized ties would allow an assumption of twice that life as not extravagant.

In all calculations of the advantage in the use of ties of longer life an important one is often overlooked, namely, the reduced necessity of disturbing the track, with all the advantages which that implies.

The value of this indirect advantage, to be sure, it is almost impossible to establish by mathematical calculation, but the direct financial superiority of one tie system over another is perfectly capable of being figured upon a mathematical basis, and the factors to be used for such calculation are not doubtful.

There has been much difficulty experienced, even by the writers in the publication referred to of the Society of Civil Engineers, in getting at a proper basis upon which to compare the financial value of two tie systems of varying cost and duration, or the eventual saving of one over the other.

For a perpetual concern like a railroad the first cost is not always the most important factor of calculation. In fact, the saving of labor for renewals and maintenance is now the vital question in the cost of railroad management. When this is brought to a minimum by perfection of the road, safety and comfort in traveling as well as a safe dividend will be secured.

We may dismiss at once as improper in a community with well established financial systems any calculation which does not apply compound interest. There can be a dispute only as to the rate of interest, which in discounting long-standing investments is usually taken at less than the current rate of interest. But, while the choice of the rate is of importance when the actual amount of saving is to be calculated, if the existence only of a saving—no matter of what amount—is to be established, this choice of rate of interest becomes irrelevant as long as we use the same rate in all cases which we compare. And, especially in the case of two tie systems, the saving which the one of longer duration brings, by virtue of greater safety and permanence of road-bed, is incalculable, so that to establish its superiority financially we need to prove only that it is not more expensive.

The expenditure for a tie system, which must be renewed at given intervals, may be conceived as a series of intermittent rents. In order to make them comparable with another series of rents, which are paid out at different intervals we must transform both series into annual rents.

The sum total of the amounts represented in the intermittent rents, with compound interest discounted to the present date, are to be equal to annual rents discounted in the same way. If R = intermittent rent or charge, p = rate of interest, n = period of payment, r = annual rent or charge, we have

$$R + \frac{R}{1.0p^{n}} + \frac{R}{1.0p^{2n}} + \cdot \cdot = \frac{r}{1.0p} + \frac{r}{1.0p^{2}} + \cdot \cdot$$

Summing up both sides, which represent two endless falling geometric series, we get

$$\frac{R\,1.0p^{n}}{1.0p^{n} - 1} = \frac{r}{0.0p};$$

or

$$r = R\,\frac{1.0p^{n}}{1.0p^{n} - 1}\,0.0p$$

This is the only proper way of determining the so-called annual charge, and with this formula a table of annual charges has been constructed and appended to this report, which allows ready comparison of systems of varying cost and duration as to their profitableness. This table is calculated for a 5 per cent. rate of interest.

If a lower rate of interest is used in calculating the annual charges, these, to be sure, fall out lower, but the amounts of saving increase. So that it may be assumed that the table calculated upon a 5 per cent. basis gives the most conservative, practically applicable results.

If the actual amount saved is to be determined, we need only find and compare the capitals which produce annually if placed on simple interest the amounts of the annual charge; or to arrive at the amount of that capital directly, we need only omit in the above formula the multiplication with $0.0p$. Calling $C + R = S$, the sum from which we may take the amount R for first construction and have the amount C left to produce R at stated intervals of n years, we have

$$S = R \frac{1.0p^n}{1.0p^n - 1}$$

Using the table of annual charges, we see that a tie costing 30 cents and lasting 5 years involves an annual charge of 6.93 cents, which corresponds to a capital of $1.39. Were we to pay 20 cents more for a tie lasting ten years, the annual charge would be 6.47 cents, corresponding to a capital of $1.29; or use of the latter ties would mean a capital saving of 10 cents per tie or $260 per mile of track laid with 2,600 ties.

This does not include the saving which comes by virtue of the less frequent necessity of renewal, and which can be determined in a similar manner; a table of annual renewal charges is also appended.

If objections should be made to employing indefinite time, as has been here done, in the capitalization, and it is desired to relate the capital to any given term for which the business is supposed to run, the following formulas should be employed, representing the accumulation of recurring expenditures, with compound interest at the end of the business term:

R = amount paid out once in n years,
m = the number of terms of n years,
V = the total value of the investment at the end of $m\,n$ years,
p = the rate of interest; then

$$V = R \frac{(1.0p^{mn} - 1)\ 1.0p^n}{1.0p^n - 1} \tag{1}$$

If we consider two systems in which the corresponding values are $V_{\prime}$, $R_{\prime}$, $m_{\prime}$, $n_{\prime}$, and $V_{\prime\prime}$, $R_{\prime\prime}$, $m_{\prime\prime}$, $n_{\prime\prime}$, we have from (1)

$$V_{\prime} = \frac{R_{\prime}\ 1.0p^{n_{\prime}} (1.0p^{m_{\prime}n_{\prime}} - 1)}{1.0p^{n_{\prime}} - 1}$$

(2)

$$V_{\prime\prime} = \frac{R_{\prime\prime}\ 1.0p^{n_{\prime\prime}} (1.0p^{m_{\prime\prime}n_{\prime}} - 1)}{1.0p^{n_{\prime\prime}} - 1}$$

Since for comparison we must have $m_{,}n_{,}=m_{,,}n_{,,}$ the values (2) give

$$\frac{V_{,}}{V_{,,}}=\frac{R_{,}}{R_{,,}}\frac{1.0p^{n_{,,}}-1}{1.0p^{n_{,}}-1}\,1.0p^{n_{,}-n_{,,}} \qquad (3)$$

From this we see that the first or second system will be the more advantageous, according as $\frac{V_{,}}{V_{,,}}$ is less or greater than 1.

If, for instance, we introduce into these equations the following elements, in one case a tie costing 60 cents in the roadbed, lasting eight years, in the other case a tie costing the same but lasting sixteen years, 2,600 ties to the mile, we find for a term of thirty-two years, in the first case an expenditure of investment and accumulated interest of \$18,131.18, and in the other case of \$10,836.42, or, since

$$\frac{V_{,,}}{V_{,}}=\frac{2600\times60\times1.05^{8}-1\times1.05^{8}}{2600\times60\times1.05^{16}-1}=0.60,$$

the saving of the longer-lived tie amounts to 40 per cent. By discounting the difference in accumulated expenditures after thirty-two years, namely, \$7,294.76 to the present year, according to formula $E=\frac{A}{1.0p^{n}}$, we get the present capital saving, namely, \$1,531.90. This represents the financial advantage of the tie of longer duration for a thirty-two year run. For a longer run this amount increases naturally.

The simplest and most satisfactory way, however, of comparing two systems is by taking recourse to a calculation of annual charges.

ANNUAL CHARGES.

As we have seen the expenditure R occurring now and recurring every n years, like that for the renewal of railroad ties, is changed into an annual charge r by the formula as developed above

$$r=R\frac{1.0\,p^{n}\,0.0\,p}{1.0\,p^{n}-1}$$

in which p is the rate of interest and $1.0\,p=\frac{100+p}{100}$

In the following table the fraction $\frac{1.0\,p^{n}\,0.0\,p}{1.0\,p^{n}-1}$ has been computed for rate of interest at 5 per centum, and for various terms of n.

By multiplying the fraction, given for 1 cent expenditure, under the term in which the expenditure is to recur, with the actual amount of the expenditure in cents the annual charge is found.

This multiplication is carried out in the table for varying expenditures from 20 cents to 125 cents.

If the expenditure is not now incurred, but becomes first necessary after n years and then recurs at intervals of n years, like the cost of replacing railroad ties (assuming that first laying is done at a different figure), the formula for the annual charge is changed into

$$r=\frac{\mathrm{R}\quad 0.0p}{1.0p^{n}-1}$$

For this the needful computations are found in Table II.

Examples.

(1) A hemlock tie, costing 40 cents in the road-bed, lasts five years; how long must it last to allow an additional expenditure of 25 cents for a process of impregnation without increasing its ultimate cost?

Find under column 5 (years) the annual charge for 40 cents = 9.23; find for 40 + 25 = 65 cents the annual charge nearest in amount to 9.23, this, being 9.14, belongs to column 9 (years); so that to justify the expenditure a duration of between eight and nine years must be attained.

(2) A railroad company is offered hemlock ties at 25 cents which will last five years, and oak ties which will last eight years costing 45 cents. Which is cheaper, when the cost of replacing is 15 cents?

	Cents.
Find from Table I for 25 cents under column 5 (years) the annual charge	5.78
Add from Table II for cost of replacing every 5 years annual charge for 15 cents	2.72
Annual charge for hemlock tie =	8.50
Find for 45 cents under colum 8 (years) the annual charge	6.96
Add for cost of replacing every 8 years at 15 cents	1.58
Annual charge for oak tie =	8.54

The oak tie under such conditions can only indirectly be cheaper by being more easily kept in condition.

(3) It is proposed to increase the life of the hemlock tie, by means of burnettizing, to sixteen years; how much can be paid for the process in order not to exceed the cost of an oak tie, and what is the amount of saving in capital over an oak tie, if the process can be kept at 20 cents per tie, when there are 2,600 ties per mile and 15 cents per tie must be paid for first laying and again for replacing?

The annual charge for the oak tie having been found, as above, to be 8.54 cents, look under column 16 (years) for an annual charge of the same or nearly the same amount; this is 8.30 cents, corresponding to an expenditure of 90 cents; add to this annual charge, that for 1 cent as many times as it is necessary to bring it up to 8.54 or 2½ by 0.09, which brings the annual charge for the hemlock tie to 8.53, corresponding to an expenditure of 92½ cents; or since the hemlock tie originally cost 25 cents we may spend 67½ cents for the preserving process and yet keep the financial value of the hemlock tie at least equal to that of the untreated oak tie.

If we can keep the cost of process at 20 cents, making the hemlock tie in the bed 25 + 20 + 15 = 60 cents, and the oak tie 45 + 15 = 60 cents, the annual charge for the oak tie is 9.28, or per mile of 2,600 ties $241.28; the annual charge for the hemlock tie is 5.53, or per mile of 2,600 ties $143.78; the capital corresponding to these charges, bearing interest at 5 per cent., would be

For oak	$4,825.60
For hemlock	2,875.60
Difference	1,950.00

That is to say, although the original expenditure is the same in both cases, namely, 60 × 2,600 = \$1,560, in the long run the tie of twice the duration effects a saving of more than its original cost.

(4) A metal tie costing \$1.25, lasting thirty years, and then being worth for old iron 50 cents, requires an expenditure of 30 cents to lay down first and then of 40 cents for replacing; what is the proper annual charge?

	Cents.
The annual charge for \$1.25 through 30 year terms, according to Table I, is....	8.12
This is diminished by the annual charge on 50 cents recurring after the first term of thirty years, according to Table II, namely, ...	0.75
	7.37
To this must be added from Table II, the annual charge on 40 cents, recurring every thirty years after the first term = ...	0.60
	7.97
and also the annual charge for the initial expenditure of 30 cents occurring only once according to formula $r = R\frac{1.0p^{n}.0.0p}{1.0p^{n+1}-1}$ which for $n = \infty$ becomes $= \frac{R\,0.0p}{1.0p}$	
or for 30 cents and 5 per cent. rate of interest...................... $\frac{30\times0.05}{1.05} =$	1.43
making total proper annual charge	9.40

Such a tie, then, would be financially superior to an oak tie costing 55 cents laid and lasting seven years, or to a preserved tie costing 85 cents in the road-bed and lasting twelve years, as can be readily seen by finding the corresponding annual charges in Table I.

TABLE I.—*For computing annual charge of initial expenditures.*

Expenditure.	Term of years.																		
	4.	5.	6.	7.	8.	9.	10.	11.	12.	13.	14.	16.	18.	20.	22.	24.	26.	28.	30.
	Cents.	*Cents.*	*Cents.*	*Cents.*	*Cents.*	*Cents.*	*Cents.*	*Cents.*	*Cents.*	*Cents.*	*Cents.*	*Cents.*	*Cents.*	*Cents.*	*Cents.*	*Cents.*	*Cents.*	*Cents.*	*Cents.*
1 cent........	0.282	0.231	0.197	0.173	0.155	0.140	0.129	0.120	0.112	0.106	0.101	0.092	0.085	0.080	0.076	0.072	0.069	0.067	0.065
20 cents.......	5.64	4.62	3.94	3.45	3.10	2.81	2.59	2.40	2.24	2.13	2.02	1.84	1.71	1.60	1.52	1.45	1.39	1.34	1.30
25 cents.......	7.05	5.77	4.93	4.32	3.87	3.52	3.23	3.00	2.80	2.66	2.53	2.31	2.14	2.00	1.89	1.81	1.73	1.67	1.62
30 cents.......	8.46	6.93	5.91	5.18	4.64	4.22	3.89	3.61	3.38	3.19	3.03	2.76	2.56	2.40	2.27	2.17	2.08	2.01	1.95
35 cents	9.87	8.08	6.89	6.04	5.41	4 92	4.53	4.21	3.93	3.72	3.53	3.22	2.99	2.80	2.65	2.53	2.43	2.34	2.27
40 cents.......	11.28	9.23	7.88	6.90	6.19	5.62	5.18	4.81	4.49	4.25	4.04	3.69	3.42	3.20	3.03	2.89	2.78	2.68	2.60
45 cents.......	12.69	10.39	8.86	7.76	6.96	6.32	5.82	5.41	5.04	4.78	4.54	4.15	3.84	3.61	3.41	3.26	3.12	3.01	2.92
50 cents.......	14.10	11.54	9.85	8.63	7.74	7.03	6.47	6.01	5.60	5.32	5.05	4.61	4.27	4.01	3.79	3.62	3.47	3.34	3.25
55 cents.	15.51	12.70	10.84	9.49	8.51	7.73	7.12	6.61	6.15	5.85	5.55	5.07	4.70	4.41	4.17	3.98	3.82	3.68	3.57
60 cents.......	16.91	13.85	11.82	10.35	9.28	8.43	7.72	7.21	6.71	6.38	6.06	5.53	5.12	4.81	4.55	4.34	4.16	4.01	3.90
65 cents.......	18.32	15.00	12.81	11.22	10.06	9.14	8.41	7.81	7.26	6.91	6.56	5.99	5.55	5.21	5.93	4.70	4.51	4.35	4.22
70 cents.......	19.73	16.16	13.79	12.08	10.83	9.84	9.06	8.41	7.82	7.44	7.07	6.45	5.98	5.61	5.31	5.07	4.86	4.68	4.55
75 cents.......	21.14	17.31	14.78	12.94	11.61	10.54	9.71	9.01	8.37	7.98	7.57	6.91	6.41	6.01	5.69	5.43	5.21	5.02	4.87
80 cents.......	22.55	18.47	15.76	13.81	12.38	11.25	10.36	9.62	8.93	8.51	8.08	7.37	6.83	6.41	6.06	5.79	5.55	5.35	5.20
85 cents.......	23.96	19.62	16.75	14.67	13.15	11.95	11.00	10.22	9.48	9.04	8.58	7.83	7.26	6.81	6.44	6.15	5.90	5.69	5.12
90 cents.......	25.37	20.97	17.73	15.53	13.93	12.65	11.65	10.82	10 04	9.57	9.09	8.30	7.69	7.21	6.82	6.51	6.25	6.02	5.85
95 cents.......	26.78	21.93	18.72	16.39	14.70	13.35	12.30	11.42	10.59	10.10	9.59	8.76	8.12	7.62	7.20	6.89	6.59	6.36	6.17
100 cents.......	31.19	23.08	19.70	17.26	15.48	14.06	12.95	12.02	11.15	10.64	10.10	9.22	8.54	8.02	7.58	7.25	6.94	6.69	6.50
105 cents.......	32.60	24.24	20.69	18.12	16.25	14.76	13.59	12.62	11.70	11.17	10.60	9.68	8.97	8.42	7.96	7.61	7.29	7.03	6.82
110 cents......	34.00	25.39	21.67	18.98	17.02	15.46	14.24	13.22	12.26	11.70	11.11	10.14	9.40	8.82	8.34	7.97	7.63	7.36	7.15
115 cents.......	35.41	26.54	22.66	19.85	17.80	16.17	14.89	13.82	12.81	12.23	11.61	10.60	9.82	9.22	8.72	8.38	7.98	7.70	7.47
120 cents......	36.82	27.70	23.64	20.71	18.57	16.87	15.53	14.42	13.37	12.76	12.12	11.06	10.25	9.62	9.10	8.70	8.33	8.03	7.80
125 cents.......	38.23	28.85	24.63	21.57	19.35	17.57	16.18	15.02	13.92	13.30	12.62	11.52	10.68	10.02	9.48	9.06	8.68	8.37	8.12
Add for each additional 5 cents	1.410	1.154	0.985	0.863	0.774	0.703	0.647	0.601	0.560	0.532	0.505	0.461	0.427	0.401	0.379	0.362	0.347	0.334	0.325

TABLE II.—*For computing annual charge of renewal.*

Expenditure.	Term of years.																		
	3.	4.	5.	6.	7.	8.	9.	10.	11.	12.	14.	16.	18.	20.	22.	24.	26.	28.	30.
	Cents.	*Cents.*	*Cents.*	*Cents.*	*Cents.*	*Cents.*	*Cents.*	*Cents.*	*Cents.*	*Cents.*	*Cents.*	*Cents.*	*Cents.*	*Cents.*	*Cents.*	*Cents.*	*Cents.*	*Cents.*	*Cents.*
1 cent.......	0.317	0.232	0.181	0.147	0.123	0.105	0.09	0.079	0.07	0.063	0.051	0.042	0.039	0.03	0.026	0.023	0.019	0.017	0.015
10 cents.......	3.17	2.32	1.81	1.47	1.23	1.05	0.90	0.79	0.70	0.63	0.51	0.42	0.39	0.30	0.26	0.23	0.19	0.17	0.15
12 cents.......	3.80	2.78	2.17	1.76	1.48	1.26	1.08	0.95	0.84	0.76	0.61	0.50	0.47	0.36	0.312	0.28	0.23	0.20	0.18
15 cents.......	4.76	3.48	2.72	2.21	1.85	1.58	1.35	1.19	1.05	0.95	0.77	0.63	0.59	0.45	0.39	0.35	0.29	0.26	0.24
20 cents.......	6.34	4.64	3.62	2.94	2.26	2.10	1.80	1.58	1.40	1.26	1.02	0.84	0.78	0.60	0.52	0.46	0.38	0.34	0.30

REPORT ON THE CONSUMPTION OF TIES AND OTHER LUMBER BY RAILROADS IN THE UNITED STATES.

The following tabulation is made up from reports of the railroad companies named, kindly furnished in answer to a circular of inquiry.

The various roads have been grouped in sections, in order more readily to compare their requirements for wood material with conditions of supply. The foot-notes are made up from the general statements accompanying reports or from published annual reports of the roads. The roads are numbered consecutively, and foot-notes refer to the roads whose numbers they bear.

To admit a comparison of prices, those reported to this Department in a similar canvass six years ago have been added in italics.

The summary which heads the tabulation of separate reports is calculated upon the basis of these reports; the mileage of total track, where not stated in the reports, has been based upon that given in Poor's Manual for 1888, with due consideration of double track and sidings. The mileage of roads reporting refers to either 1888 or 1889, and the reports themselves cover varying periods of twelve months during this period.

Altogether, approximations only can be expected from inquiries of this kind, but they are quite sufficient for the purposes in view.

In regard to the summary, the following remarks are in place.

The number of ties per mile in track has been ascertained by multiplying the reported mileage of each road by the number of ties used for each mile of road, adding up the sums thus obtained and dividing by the total mileage reported in the section. From this the total number of ties in track appears to be 515,892,918.

The number of ties used for renewal is evidently an understatement of average conditions, since this would make the average life of ties eight and three-fourths years, which it is impossible to believe. It is likely that in many cases the year for which the report was made has been one in which, for various reasons, less replacement has been effected than usual on the reporting roads. The increased new mileage, especially of Western roads, also tends to make the proportionate requirement for renewals appear less than it is in reality. By taking the proportionate number of ties of various timbers used as calculated upon the percentages of each reported, multiplying this by the average life for each kind and dividing by the total number of ties laid in the year of the report, the average life per tie would come to 6.6 years. This would bring the annual average requirement for renewal to round 80,000,000 ties, which is probably nearer the truth and brings the average number of ties per mile needed for renewals to 417, or 15.5 per cent. of ties in track.

One of the roads reporting has adopted a simple method of ascertaining the durability of ties, by making a notch on the face of the tie, near one end, on placing it in the track, and adding a notch each year afterwards while it remains in the roadbed.

The cross-section of ties, as commonly used by the various roads (the + sign in the tabulation denoting that larger cross-sections are also employed), allows a ready calculation of the size of the tie.

There is a wide range in the area of cross-sections, extending from 36 to 90 inches, making a variation in the solid contents of the tie from 3.15 to 8.55 cubic feet. While in some cases the larger dimensions indicate inferior timber, in many cases the best and most valuable timber is used for ties of the largest size.

In thickness, 6 inches are specified commonly by the roads of the New England, Central Northern, Northwestern, and Southwestern groups, while the Middle Atlantic, South Atlantic, and, to some extent, the Central Northern and Guif groups prefer ties 7 inches thick. As to width, the New England roads demand usually an average of 6 inches, and in two cases only 5. A width of 7 inches is called for in all the groups, but chiefly by the Middle Atlantic and Central Northern. Half the call for ties 8 inches in width is from the Central Northern group, the balance mainly from southern regions, and the demand for a width of 9 inches is mostly from the South. While, no doubt, the weight of the tie, approximately indicated by its cross-section, is an important factor in its efficient service, it is questionable whether these large cross-sections are chosen and adjusted with this demand in view. Probably local conditions, which allow or make more convenient the use of large dimensions (as from the virgin forests in the South), dictate these specifications.

There is great diversity in the dimensions of ties used. Of the roads reporting, 51, or 62.5 per cent. of all, use ties 8 feet in length, and 10, or a little more than 12.5 per cent., demand ties 9 feet long. Ties of 8 feet length are used in all the groups except the Gulf and Middle Atlantic. Ties 8½ feet in length are used chiefly in the Middle Atlantic and Central Northern groups, while those 9 feet in length are used almost exusively in the South Atlantic and Gulf groups.

Reports on the consumption of forest supplies by railroads.

SUMMARY FOR THE WHOLE COUNTRY.

No.	Districts.	Miles of track.	Miles reported.	Per cent. of total track reported.	Ties per mile in track.	Ties used annually for renewal by reporting roads.	Proportionate number used by all roads.	Ties per mile for renewal.	Kinds of timber used for ties.	Percentage of each.	Average prices.	Bridge and other lumber used annually by roads reporting.	Average amount of lumber per mile used annually by roads reporting.	Proportionate amount of lumber used by all roads.
												Feet, B.M.	*Feet, B. M.*	*Feet, B. M.*
1	New England group..	10, 813	6, 506	60. 2	2, 752	2, 373, 000	3, 941, 860	365	Chestnut .	52	36–55	24, 499, 202	3, 766	40, 721, 758
									Oak	6	36–55			
									Cedar	26	33			
									Various ..	16	35–47			
2	Middle Atlantic group	31, 281	23, 135	73. 9	2, 728	7, 067, 850	9, 543, 318	305	Oak	73	40–70	*64, 613, 262	4, 449	100,898,871+
									Chestnut .	8	25–60			
									Pine......	11	46–64			
									Cedar.....	5	35–53			
									Various ..	3				
3	South Atlantic group.	16, 224	6, 256	38. 6	2, 726	2, 471, 188	6, 402, 041	395	Oak	43	25–33	27, 593, 036	4, 411	71. 564, 064
									Pine......	50	20–25			
									Cypress ..	7	27–28			
4	Northern Central group.	56, 032	33, 519	60. 1	2, 916	9, 149, 667	15, 224, 071	272	Oak	78	25–55	130, 391, 938	4, 092	229, 282, 944
									Cedar	11	15–40			
									Tamarack	3	15–18			
									Hemlock .	5	15–18			
									Various ..	3				
5	Gulf and Mississippi group.	12, 522	5, 558	44. 4	2, 770	2, 026, 400	4, 563, 964	365	Oak	68	25–29	9, 300, 500	3, 167	39, 657, 174
									Pine......	32	20–25			
6	Northwestern group..	20, 744	16, 961	81. 8	2, 759	5, 411, 974	6, 681, 449	319	Oak	40	31–60	46, 242, 425	2, 863	59, 390, 072
									Elm	4				
									Pine......	26	18–39			
									Various ..	30	16–33			
7	Southwestern and Pacific group.	43, 881	20, 520	46. 8	2, 310	6, 377, 785	3, 752, 584	311	Redwood .	15	30–53	53, 618, 185	3, 188	139, 892, 628
									Cedar	7	22–38			
									Fir	5	22–38			
									Pine......	15	25–34			
									Oak	54	26–75			
									Cypress ..	4				
	Totals..	191, 497	112, 455	58. 8	2, 694	34, 877, 864	60, 034, 647	310	....	....	....	356, 258, 548	3, 748	681, 407, 511

* Returns from the Pennsylvania Railroad and from the eastern division of the Baltimore and Ohio included no report as to the amount of lumber used, and the above estimate is made without reference to those roads, which include 8,602 miles of track, or more than one-third of the whole mileage of the group. These roads use iron, brick, and stone for bridges and buildings more largely than other roads, but it would probably be fair to add 25 per cent. to the above estimate on their account.

Reports on the consumption of forest supplies by railroads—Continued.

NEW ENGLAND GROUP.

[NOTE.—Words and figures in italics represent the reports from an inquiry on the subject of the consumption of forest supplies by railroads made eight years ago and are reproduced in the present case for the purpose of comparison.]

No.	Roads.	Length of track.	Ties.							Bridge and other lumber used.
			Average no. in track per mile.	Used for renewal for year reported.	Per mile for renewal.	Kinds of timber.	Price.	Cross-section.	Where obtained.	
										Feet—B. M.
1	Connecticut River	158	2,640	64,600	405	Chestnut	22½–45	35+	On line of road	350,000
						Chestnut	*40*			
2	Boston and Maine	1,210	2,640	600,000	496	Cedar	33	36+	On line of road	8.000,000
						Cedar	*33*			
3	Bennington and Rutland	70	2,500	44,000	628	Red oak				
						Chestnut	36	48	On line of road	65,500
						Hemlock				
4	Fitchburg	730	2,800	250,000	343	Chestnut	42	42	On line of road	2,500,000
						Chestnut	*50*			
5	Boston and Albany	858	2,640	285,000	332	Chestnut	50	49	On line of road	800,000
						Chestnut	*51*			
6	New York and New England	730	2,600	250,000	340	Chestnut, 90 per cent	35–50	49+	On line of road	2,270,000
						Oak, 10 per cent	40			
						Oak and chestnut	*38–45*			
7	New York, New Haven and Hartford	1,066	2,800	300,000	281	Chestnut, 75 per cent	44	36+	On line of road	7,438,702
						Oak, 25 per cent				
						Oak and chestnut	*48*			
8	Central Vermont	736	3,000	250,000	340	Hemlock	35–40		Canada	1,500,000
						Tamarack				
						Hemlock	*15–25*			
						Tamarack	*31*			
9	Housatonic	230	2,700	800,000	348	Chestnut, 66 per cent	38	36+	On line of road	150,000
						Oak, 34 per cent				
10	New York, Providence and Boston	216	2,992	100,000	463	Chestnut, 75 per cent	45–55	49+	On line of road	625,000
						Oak, 25 per cent				
						Chestnut and oak	*50*			
11	Long Island	502	2,889	150,000	300	Yellow pine, 55 per cent	47			800,000
						Spruce, 30 per cent	37			
						Chestnut, 10 per cent	40			
						Various, 5 per cent	90			
	Totals	6,506	2,752	2,373,000	365					24,499,202
									Per mile	3,766

1. Two hundred acres of woodland owned. Price of ties lower than twenty years ago. Outlook good for what we require. 2. Formerly used kyanized hemlock eight years, at cost of 10 cents per tie. Cedar now so cheap and hemlock so dear, the process has been abandoned. 4. Supply of ties and posts increasing. 5. Pine and chest-

nut plenty for several years to come. More ties offered than are wanted. 6. White oak growing scarce. Chestnut more plenty. Using some creosoted timber. 7. Supply probably decreasing, but more ties offered than are needed. 8. Own 2,000 acres of growing timber. No material change in price of ties for several years. 10. Supply of ties good for fifteen or twenty years. 11. Timber supply decreasing. Have put in creosoted ties this year as an experiment, at double the cost of untreated ties. Fernolined timbers put in interlocking signal foundations three years ago show no signs of decay.

MIDDLE ATLANTIC GROUP.

12	New York Central and Hudson River.	3, 723	2, 800	660, 000	177	Pine, 48 per cent	60		54+	Pine from Georgia, oak and cedar from Michigan, chestnut from Pennsylvania.	16, 455, 323
						Oak, 23 per cent	60				
						Cedar, 8 per cent	40				
						Chestnut, 21 per cent	60				
						Pine		77			
						Oak		80			
						Cedar		53			
						Chestnut		62			
13	Delaware, Lackawanna and Western	1, 746	2, 900	895, 756	513	Pine, 22 per cent	....		42+	....	19, 185, 000
						Oak, 59 per cent					
						Cedar, 8 per cent					
						Chestnut, 11 per cent					
						Pine		25			
						Oak		75			
						Cedar		33			
						Chestnut		45			
14	New York, Ontario and Western	480	3, 000	174, 000	362	Chestnut, 50 per cent	35		42+	⅔ on line of Maryland, ⅓ from the south, and from Canada.	1, 320, 890
						Oak, 10 per cent	45				
						Pine, 20 per cent	46–50				
						Cedar, 20 per cent.					
15	New York, Lake Erie and Western	2, 869	2, 800	700, 000	244	Oak, 82 per cent.; chestnut, 18 per cent.	55		49+	On line of road, Virginia and West Virginia.	5, 320, 050
						Oak		65			
						Chestnut		50			
16	New York, Susquehanna and Western	198	2, 816	66. 377	335	Oak, 75 per cent.; chestnut, 25 per cent	45–50		49	On line of road	309, 520
						Chestnut		45			
17	Rome, Watertown and Ogdensburg	773	2, 800	300, 000	388	Cedar, 53 per cent.; oak, 14 per cent.; chestnut, 2 per cent.; tamarack, 23 per cent.; hemlock, 8 per cent.	....		48	Canada	2, 494 243
18	Central Railroad of New Jersey	1, 167	2, 600	290, 159	248	Oak, 43 per cent	67		49+	$\frac{7}{10}$ on line, $\frac{3}{10}$ from south	2, 062, 500
						Chestnut, 21 per cent	41				
						Pine, 18 per cent	64				
						Cypress, 14 per cent	55				
19	Pennsylvania Railroad, east of Pittsburg.	6, 596	2, 640	2, 500, 000	379	Oak	40–70		49+	Partly on line, partly Maryland, Virginia, and Carolinas.	
						Oak		80			
20	Allegheny Valley	401	2, 600	95, 338	238	Oak	40		63	On line	300, 000+
21	Erie and Pittsburg	124	2, 800	40, 000	323	Oak Cherry Locust	43–53		56+	....	1, 030, 751

Reports on the consumption of forest supplies by railroads—Continued.

MIDDLE ATLANTIC GROUP—Continued.

No.	Roads.	Length of track.	Ties.							Bridge and other lumber used.
			Average no. in track per mile.	Used for renewal for year reported.	Per mile for renewal.	Kinds of timber.	Price.		Cross-section.	Where obtained.	
22	New Castle and Beaver Valley	24	2,800	7,631	317	Oak Cherry Locust	43-53		56+		*Feet—B. M.* 63,314
23	Baltimore and Ohio, East division	2,006	2,600	605,000	302	Oak	40		49+	On line	
						Oak		30-50			
	West division	878	3,000	243,588	277	Oak	40		56+	On line	4,520,671
						Oak		40			
24	Philadelphia and Reading	2,150	2,650	500,000	233	Oak, 30 per cent Chestnut, 10 per cent Pine (yellow), 60 per cent	60 40 50		56+	Line of road and Southern States.	11,551,000
	Totals	23,135	2,728	7,067,850	305						*64,613,262
										Per mile	4,449

12. Since the war have been using Georgia pine in part for ties on account of difficulty of procuring oak and chestnut. Eight hundred thousand ties are reported as the average number used for repairs. 13. Use iron for bridges. 14. Increase in price of southern ties about 5 cents. No increase for three or four years in price of those procured on line of the road. Use fernoline in timber trestles on all joints and surfaces in contact. 16. Price of ties advancing. Looks as though the time is coming when we shall have to look to other countries for timber. 18. Supply on line of road decreasing. Put in a few creosoted ties eighteen years ago. 19. Price not increased, but quality deteriorating. 23. Ties becoming scarce on line of road. During the year ending September 30, 1888, the account for material and labor included 259,315 ties on the division west of the Ohio River, $107,993.92, or 41⅝ cents per tie; 609,462 ties on the division east of the Ohio River, $213,586.83, or 35 cents per tie.

* It will be noticed that no report of lumber used by the Pennsylvania Railroad Company or by the eastern division of the Baltimore and Ohio is made. More than one-third of the mileage of this group is therefore left out of the report of lumber consumed, and this needs to be taken into account.

SOUTH ATLANTIC GROUP.

25	Florida Southern	323	2,640	173,070	536	Pine	20		70+	On line	300,000
26	Florida Central and Peninsular	594	2,640	250,000	421	Pine, 80 per cent Cypress, 20 per cent	22½ 27		59+	On line	534,000
27	Savannah, Florida and Western	660	2,640	330,000	500	Pine	25		70	On line	4,000,000
						Pine		25			
						Cypress		30			
28	Weldon and Wilmington	858	2,580	316,232	368	Pine, 86 per cent Oak, 14 per cent	20 33.3		49+	On line	3,316,514

29	South Carolina Railway Company	287	2,640	117,137	408	Cypress, 98 per cent	28		70	On line	963,450
						Pine, 2 per cent	22				
					*	*Cypress*		28			
						Pine		22			
30	Richmond and Danville	427	2,992	166,750	390	Oak	29½		49+	On line	3,903,160
31	Virginia Midland and Washington and Ohio.	405	2,816	239,445	591	Oak	30		48–56	On line	3,167,500
						Oak		35			
32	Western North Carolina	382	2,640	108,000	283	Oak	30		63	On line	2,119,561
33	North Carolina Division	290	3,000	84,554	291	Oak	31½		56	On line	750,000
34	Atlanta and Charlotte	409	2,640	140,000	342	Oak	15–31		56+	On line	2,675,000
35	South Carolina Division	393	2,900	156,000	399	Oak, 54 per cent	14–27		56+	On line	1,087,390
						Pine, 46 per cent	23.3				
36	Columbia and Greenville Division.	298	2,816	160,000	537	Oak, 25 per cent	30		56+	On line	1,746,461
						Pine, 75 per cent	25				
37	Georgia Pacific, First Division	210	2,816	100,000	476	Pine, 67 per cent	25		63+	On line	1,050,000
						Oak, 33 per cent	25				
38	Georgia Pacific, Second Division	226	2,816	80,000	354	Oak	25		63+	On line	1,230,000
39	Newport News and Mississippi Valley.	494	....	50,000	101	Oak	25		56	On line	750,000
	Totals	6,256	2,726	2,471,188	395	....	....		....	....	27,593,036
										Per mile	4,411

25. Own 1,500,000 acres of pine and cypress. Ample supply for ten years. 26. Timber supply good at present. 27. Have begun to use creosoting process on piling and bridge timber. 28. Have used some creosoted ties for three years. 29. The company has 20,000 acres of woodland, but reserves its own timber and gets supplies mainly from other parties. 30. Supply, except for ties, insufficient. Pine obtainable only in limited quantities. 33. Bridge timber rather scarce. 34. Price of ties advanced 20 per cent. 37. Very soon timber will be hard to obtain. 38. Pine timber scarce. Oak on part of the line, but will soon be less easy to get.

NORTHERN CENTRAL GROUP.

40	Cleveland and Pittsburgh	303	2,816	75,000	248	Oak	35–50		56+	West Virginia	2,195,000
						Oak		56			
						Cedar		50			
41	Cleveland, Akron and Columbus	194	2,640	50,000	258	Oak	42		56	On line, Michigan and elsewhere.	175,000+
						Oak		45			
42	Pittsburgh, Youngstown and Ashtabula	164	2,800	53,430	....	Oak	43–53		56+	....	1,319,396
						Oak		55			
43	Illinois Central	(3,478)	2,640 to 2,816	395,348	114	Oak	37		48+	Line of road	6,069,508
					(258)			30–50			
44	Chicago and Eastern Illinois	420	3,000	140,000	333	Oak	33		48	Line of road	1,600,000
								36			
45	Chicago, Rock Island and Pacific	3,143	3,000	200,000	190	Hemlock, 33 per cent	....		48	Mostly on line	11,500,000
				400,000	(280)	Oak, 67 per cent					
46	Chicago, Burlington and Quincy	2,135	3,000	902,100	422	Oak, 80 per cent	40–54	40–60	48	Oak, Missouri and Illinois	15,367,000
						Cedar, 20 per cent	31–47		....	Cedar, Michigan and Wisconsin.	
47	Chicago and Alton	1,112	3,000	350,000	314	Cedar, 10 per cent	38		....	On line and Missouri	2,000,000
						Oak, 90 per cent					

*Burnettized.

Reports on the consumption of forest supplies by railroads—Continued.

NORTHERN CENTRAL GROUP—Continued.

No.	Roads.	Length of track.	Ties. Average no. in track per mile	Ties. Used for renewal for year reported.	Ties. Per mile for renewal.	Ties. Kinds of timber.	Ties. Price.	Ties. Cross-section.	Ties. Where obtained.	Bridge and other lumber used.
										Feet—B. M.
48	Green Bay, Winona and St. Paul	237	2,640	70,000	295	Hemlock, 57 per cent	15	42+	On line	605,000
						Tamarack, 29 per cent	15			
						Cedar, 7 per cent	15			
						Pine, 7 per cent	11			
49	Flint and Père Marquette	900	3,000	300,000	333	Hemlock, 75 per cent	15	36+	On line	500,000
						Oak, 15 per cent	30			
						Tamarack and ash, 10 per cent.	15			
						Hemlock	15			
						Oak	35			
50	Chicago and Northwestern	4,645	3,000	1,125,000	242	Oak, 60 per cent	45–55	49+	On line	18,241,468
						Cedar, 30 per cent	20			
51	Chicago, Milwaukee and St. Paul	6,788	2,990	1,800,000	265	Oak, 67 per cent	45	48+	On line, and Missouri, Indiana, and Tennessee.	36,102,197
						Cedar, 22 per cent				
						Tamarack, 11 per cent	26			
						Oak	40			
52	Detroit, Grand Haven and Milwaukee	252	2,640	111,600	444	Oak	18–40	......	On line	7,992,264
						Oak	30			
						Hemlock	18			
53	Lake Shore and Michigan Southern	2,259	2,640	711,678	315	Oak, 70 per cent	54	56+	Michigan, West Virginia, and Kentucky.	11,475,254
						Cedar, 27 per cent	31			
						Oak	47.7			
						Cedar	30.9			
54	Michigan Central	2,304	2,800	650,000	282	Oak, 75 per cent	45	48+	On line	2,000,000
						Cedar, hemlock and tamarack, 25 per cent.	18			
55	Evansville and Terre Haute	563	2,700	245,000	435	Oak	33	48	On line	1,650,000
						Oak	37½			
56	Louisville, New Albany and Chicago	599	2,760	165,000	275	Oak	30	48	Partly on line and partly other places in State.	550,000
						Oak	30			
57	St. Louis, Alton and Terre Haute	271	2,600	58,120	214	Oak	12½–25	50+	Partly on line	1,278,200
58	Northwestern Ohio	94	2,700	25,000	266	Oak	55	50+	West Virginia mostly	50,000
59	Toledo, Peoria and Western	280	3,000	75,000	268	Oak, 84 per cent	40	50+	20 per cent. on line; 80 per cent. southern Illinois.	540,000
						Cedar, 16 per cent	40			
60	Wabash	1,827	3,000	730,000	399	Oak	......	56+	Chiefly on line	
						Locust				

61	Columbus, Hocking Valley and Toledo	450	3,000	135,000	300	Cherry ...... Oak ...... *Oak*	 40 35	63+	⅔ on line; ⅓ West Virginia..	1,378,000
62	Louisville, Evansville and St. Louis ...	352	2,900	82,391	234	Oak ...... *Oak*	25 32	48+	On line	1,392,051
63	Ohio and Mississippi	749	3,000	300,000	400	Oak ...... *Oak*	 28	59+	On line	5,511,600
	Totals ..	33,692	2,916	9,149,667	272	......	......	......	...... Per mile..	130,391,938 4,092

40. Advance of 4½ per cent. in price of ties since last year; supplies decreasing. 41. Price of ties fixed by the company; supplies sufficient for renewal, but not for construction. 43. Had land but disposed of it; timber supply declining. Number of ties stated for average of 19 years, with an average mileage of 1,530 miles. The following table of the comparative statement of maintenance of way for ten years is of interest in this connection. From this statement the remarkably low average figure of 240 ties per mile for renewal results in making the life of the oak tie and cedar, which were used formerly, over eleven years, at an average price of less than 35 cents.

Year.	Miles of road at end of year.	Maintenance of way, Illinois Central Railroad.								Repairs of fences.	Repairs of station buildings and water works.
		Labor on track.	New rails.	Cross-ties.	Repairs of bridges.	Other items.	Total.	Mileage of engines.	Expense per mile run by engines.		
1879..	1,286.72	$297,363.40	9,276.00 tons....$125,062.70	264,520.... $93,107.51	$73,119.56	$125,041.92	$640,575.53	5,460,371	11.73 cts..	$33,416.86	$45,755.09
1880..	1,320.35	343,082.23	9,767.49 " 215,365.32	260,116.... 93,330.32	105,551.62	49,399.09	807,628.58	6,513,611	12.39 cts..	36,981.04	80,887.34
1881..	1,320.35	411,018.91	10,098.47 " 169,718.80	345,260.... 127,279.76	114,193.18	30,399.46	852,610.11	7,006,532	12.16 cts..	36,690.33	70,699.58
1882..	1,908.65	690,112.59	8,438.00 " 128,521.48	604,096.... 201,648.26	174,826.24	17,277.34	1,212,385.91	10,218,008	11.87 cts..	31,032.57	87,588.26
1883..	1,927.99	742,476.20	8,191.79 " 183,239.65	425,627.... 153,739.00	121,101.03	72,294.71	1,272,850.59	10,702,152	11.89 cts..	30,084.49	87,291.93
1884..	2,066.35	706,751.86	6,342.73 " 93,446.25	462,665.... 154,083.19	173,831.23	107,236.13	1,235,348.66	10,121,434	12.20 cts..	21,394.71	94,122.03
1885..	2,066.35	749,254.19	8,747.31 " 87,331.95	508,756.... 176,835.69	164,586.39	88,126.28	1,266,134.50	11,227,043	11.27 cts..	21,932.48	94,518.19
1886..	2,149.07	705,553.82	6,376.40 " 63,238.84	492,524.... 174,515.72	172,144.65	63,976.69	1,179,429.72	11,619,353	10.15 cts..	26,668.91	123,519.83
1887..	2,355.12	760,093.33	6,092.66 " 79,917.84	573,898.... 197,989.47	250,337.47	61,441.88	1,349,779.99	13,557,308	9.95 cts..	31,905.46	129,526.76
1888..	2,552.55	847,806.67	8,172.36 " 106,372.94	654,141.... 214,130.73	310,908.42	115,898.04	1,595,116.80	14,857,053	10.74 cts..	40,423.29	170,023.85

45. The length of track reported includes more than a thousand miles of new road requiring no ties for renewal. The proper figures per mile for renewal would therefore be larger than those given above. Used Burnettized hemlock ties four years; cost of process 20 cents per tie. During the year ending March 31, 1888, with a line of 1,528 miles, 704,642 ties were used in repairs, at a cost of $308,110,41; in 1887, 527,409 ties were used, at a cost of $218,020.31. 48. Timber and tie supply near road good for twenty years. 49. Company owns land and has reserved some for growth of timber and ties. 50. Just trying Burnettized ties at Milwaukee. 51. Company have 60,000 acres of woodland in Wisconsin, mostly hard wood. The report for 1888, covering 5,678 miles, showed the expenses for renewals of ties to have been $768,960 as against $865,682 in 1887, or $135 and $152 per mile, respectively. At the end of 1888 there were 550,945 ties on hand, valued at $217,204.50. 52. The report for the year ending May 31, 1888, covering 4,210.75 miles of main track and 1,026.59 miles of side track, showed that 830,903 ties were used in repairs and renewals, at a cost of $325,358 and $147,565 for laying ties, making cost of laying 17¾ cents. There were on hand 1,094,953 ties, valued at $360,425. 53. No difficulty in securing ties. 54. Ties abundant. Prices lower than formerly. In 1887 the expenditure for renewals was $319,137. During 1888 the renewals required 723,065 ties, at a cost of $270,137.44, or 37½ cents per tie. 56. Good timber getting scarce on line of road; mills decreasing. 57. Outlook for timber supplies not favorable. 58. Price of ties increased 20 per cent. in ten years. 60. Price of ties increasing. Supply near road decreasing. 61. Timber supplies getting short. Bridge timber advancing in price. 63. Timber land abundant.

Reports on the consumption of forest supplies by railroads—Continued.

GULF AND MISSISSIPPI VALLEY GROUP.

No.	Roads.	Length of track.	Ties.							Bridge and other lumber used.
			Average no. in track per mile.	Used for renewal for year reported.	Per mile for renewal.	Kinds of timber.	Price.	Cross-section.	Where obtained.	
										Feet—B. M.
64	Alabama Great Southern	354	2, 800	170, 000	480	Oak	12–29	56+	On line	1, 600, 000
						Oak	25			
65	Louisville and Nashville	2, 622	2, 800	1, 150, 000	438	Oak, 70 per cent Pine, 30 per cent		63	On line	
						Oak	27–50			
66	Mobile and Ohio	597	3, 000	120, 000	201	Pine, 30 per cent Oak, 70 per cent	20½ 27½	56	On line	2, 250, 000
67	New Orleans and Northeastern	196	2, 800	100, 000	510	Oak, 2 per cent Pine, 98 per cent	30 25	60	On line	1, 500, 000
68	East Tennessee, Virginia and Georgia	1, 789	2, 640	486, 400	272	Oak, 63 per cent Pine, 37 per cent	35 25	63	On line	3, 950, 500
	Totals	5, 558	2, 770	2, 026, 400	365					9, 300, 500
									Per mile	3, 167

64. Price of ties increased. Suitable timber near the road nearly exhausted. 65. No report of lumber consumed by this road was obtained. The amount is probably not less than 8.000.000 feet, which may properly be added to amount given in the table. 67. Supply of pine and cypress abundant, oak and poplar limited. Creosoted trestlework. 68. Supply plentiful.

NORTHWESTERN GROUP.

No.	Roads.	Length of track.	Average no. in track per mile.	Used for renewal for year reported.	Per mile for renewal.	Kinds of timber.	Price.	Cross-section.	Where obtained.	Bridge and other lumber used.
69	Chicago, St. Paul, Minneapolis and Omaha.	1, 627	3, 000	650, 000	399	Oak, 49 per cent Elm, 29 per cent Pine, 13 per cent Various, 9 per cent	45 27 22 22	48+	Chiefly on line	9, 500, 000
						Oak *Elm* *Pine*	35 25 25			
70	Chicago, St. Paul and Kansas City	812	3, 000	100, 000	123	Pine, 80 per cent Hard wood, 20 per cent	25 48	54+		
71	Burlington, Cedar Rapids and Northern.	1, 158	2, 640	243, 708	210	Oak	43	48+	Southwest Missouri	2, 030, 695
						Oak	50			
72	Union Pacific	5, 158	2, 992	1, 550, 000	300	Oak, 39 per cent	52–60	48+	Missouri and Colorado	

						Soft wood, 61 per cent	39			Wyoming and Oregon	6, 650, 000
73	Duluth, South Shore and Atlantic	561	2, 800	75, 966	135	Cedar, 50 per cent	16–21		49+	On line	683, 000
						Hemlock, 33 per cent	16				
74	Minneapolis and St. Louis	551	2, 800	210, 000	381	Oak, 22 per cent	50		42+	One-third on line, two-thirds Wisconsin.	2, 148, 730
						Cedar, 35 per cent	33				
						Mixed, 43 per cent	40				
75	St. Paul, Minneapolis and Manitoba	3, 030	2, 640	400, 000	132	Oak, 67 per cent	36		42+	On line	6, 050, 000
						Tamarack, 33 per cent	25				
76	St. Paul and Duluth	258	3, 000	150, 000	581	Oak, 20 per cent	31		42+		1, 530, 000
						Tamarack, 25 per cent	20				
						Pine, 55 per cent	18				
						Oak		33			
						Tamarack		25			
						Pine		22			
77	Northern Pacific	3, 506	2, 600	2, 032, 300	579	Oak, 31 per cent	39		56		17, 650, 000
						Pine and spruce, 52 per cent	28				
						Tamarack, 17 per cent	30				
						Oak		35			
						Pine and Tamarack		25			
	Totals	16, 961	2, 759	5, 411, 974	319						46, 242, 425
										Per mile	2, 863

69. The road makes its price for ties. No fluctuation. 71. But little valuable timber on line of the road. 72. Three years ago had Burnettizing works in operation at Laramie, Wyo., but have no preserving process now in use. During 1887 there were used in renewals, 1,284,629 ties, as follows: 420,201 oak, 173,071 cedar, 504,975 pine, 186,382 of other kinds. The cost for renewals of ties was $732,911.05 in 1887, or 57 cents per tie, and $550,068.05 in 1886. The material on hand was as follows: 1887, ties 480,516, value $224,950.35; switch ties, 482,603 feet B. M., value $12,304.53. 1886, ties 220,359, value, $99,312.31; switch ties, 775,991 feet B. M., value $17,502.90. 75. Road owns 500,000 acres of wood land. Doing all we can to preserve timber from fire and waste. 77. Timber supply ample at present.

SOUTHWESTERN AND PACIFIC GROUP.

78	Hannibal and St. Joseph	367	3, 300	100, 000	273	Oak	20–40		42+	On line	1, 284, 000
						Oak		41			
79	Atchison, Topeka and Santa Fé	3, 700		883, 621	236	Oak, 27 per cent	48		48	Missouri and Arkansas	
						Cedar, 38 per cent	38			Wisconsin and Michigan	
						Pine, 35 per cent	34			New Mexico	
						Oak		65			
						Cedar		45			
80	Denver and Rio Grande	1, 545	3, 000	600, 000	388	Oak	75		49	Two-thirds on line, one-third Colorado and Arkansas.	5, 000, 000
						Pine Spruce Cedar	25–30				
						Pine and spruce		60			
81	St. Louis and San Francisco	1, 441	2, 850	478, 081	332	Oak	26		48+	Missouri and Arkansas	6, 241, 000
82	Kansas City, Fort Scott and Memphis	1, 192	3, 000	341, 272	286	Oak	33. 3		48+	Missouri and Arkansas	4, 272, 595
						Oak		56			
83	Missouri Pacific	3, 549	2, 640	700, 000	197	Oak	12–30		48+	Missouri and Arkansas	4, 648, 553
						Oak		36½			
84	St. Louis, Arkansas and Texas	1, 227	3, 000	736, 200	600	Oak	24		56	On line	5, 500, 000

Reports on the consumption of forest supplies by railroads—Continued.

SOUTHWESTERN AND PACIFIC GROUP—Continued.

No.	Roads.	Length of track.	Ties.							Bridge and other lumber used.
			Average no. in track per mile	Used for renewal for year reported.	Per mile for renewal.	Kinds of timber.	Price.	Cross-section.	Where obtained.	
										Feet—B. M.
85	Texas and Pacific	1,651	2,600	440,000	266	Oak, 57 per cent Pine, 34 per cent Cypress, 9 per cent	30½ 29 37	48+	On line	5,500,000
86	St. Louis, Iron Mountain and Southern	1,548	2,828	485,000	313	Oak	12–25	50+	On line	17,385,000
87	Southern Pacific	4,300	2,850	1,613,611	375	Redwood, 62 per cent Cedar / Fir / Pine } 38 per cent *Redwood*	30–53 22–36 37½	48+	Pacific coast and on line	3,787,037
	Totals	20,520	2,310	6,377,785	311					53,618,185
									Per mile	3,188

78. Outlook for supply along the line poor. 79. Use Wellhouse process for timber and ties. Have a timber plantation at Hutchinson. 81. Supply of timber ample. 82. During 1888, 307,985 ties were used for renewal at a cost of $112,123 or 36.4 cents per tie. 83. During 1888, on a mileage of 3,119 miles, 1,465.121 ties were put in the track at a cost, including labor, of $365,582 or equal to 38.33 cents per tie; also 704 sets of switch ties put in the track at a total cost, including labor, of $39.29 per set. 85. Timber abundant for years to come. From December 15, 1885, to May 31, 1888, there were 2,176,768 new ties used, costing 36½ cents each, or a total of $728,365.09. The cost of ties in the maintenance of way account was $215,603.57 in 1887; and $129,531.99 in 1888. 86. Supply ample; mills increasing. 87. Report gives valuable information in regard to diminution of timber supplies by fires and by theft; company has a large grant of Government land, which is being sold to liquidate debt of the company for construction; has just established a timber preserving plant at a cost of $43,700.

REPORT

ON THE

SUBSTITUTION OF METAL FOR WOOD IN RAILROAD TIES,

BY

E. E. RUSSELL TRATMAN, C. E.

LETTER OF TRANSMITTAL.

103 Tribune Building,
New York City,
January 31, 1890.

Sir: Herewith I submit my final report upon the use of metal track on railways as a substitute for wooden ties.

This report presents at considerable length, and in considerable detail, the development of the use of such track in many foreign countries, the experience thus obtained and the present state of the metal track question. The bulk of the information has been obtained from official sources. Foreign railway managements as a rule have manifested great courtesy and a willingness to furnish full information both in regard to the various systems of track, the conditions of service, and the results obtained. In order to show the thoroughness of my investigation, I may state that my memoranda show personal letters of application for information written to over three hundred individuals, of whom about two hundred have replied. A large number of the replies have been very full and complete, and have been accompanied by drawings, reports, etc. Many of these returns necessitated further correspondence, asking for missing links of information, more complete data, etc., or sending information requested by the persons making the returns. The total of the direct correspondence has amounted to about six hundred letters, with about three hundred communications received. These figures are exclusive of requests for information included in private or general business correspondence. Circulars containing a request for information, with a list of questions showing the character of the information desired, have been sent out with most of the letters of inquiry, and have also been sent to many of the foreign technical and engineering papers. A copy of the circular is appended. In all, about five hundred of these circulars have been sent out. Most of the information obtained, and that of the most complete and valuable character, has been received in answer to the personal letters of application for information. The American and foreign technical and engineering journals have been studied for published information relating to the matters under investigation.

The report presents the results of more than two years of direct work and investigation for this special purpose, but the subject is one which has occupied my attention for a longer time.

It will of course be understood that the rail support itself can not be considered independently, and therefore detailed information is presented in regard to conditions of track, traffic, and rolling stock, all of which conditions have an important bearing upon the general question of the substitution of metal for wooden supports for the rail.

The report covers, as will be seen by the tabular summary accompanying it, nearly 25,000 miles of railway laid with metal track, out of a total mileage of the world (exclusive of the United States and Canada) of 187,721 miles, or a relation of 13.21 per cent. to this total mileage. Allowing for omissions (which will necessarily occur in a work of this extent), incomplete returns, figures not brought up to recent date, etc., there is probably a total length of about 30,000 miles of railway having metal track, or a relation of nearly 16 per cent. to the total mileage of the world (exclusive of the United States and Canada). These few figures show at a glance the great importance of the subject considered in this report, and show also that in other countries the subject has long ago passed the experimental stage in which it still rests in this country. The first part of the report is devoted to details, descriptions, and statistics relating to the several railways, and this matter is compiled mainly from official returns and statements. The second part of the report consists of a general review of the subject, and a summary of the information on several points.

I am particularly pleased to be able to show in this report that in the United States the subject is now receiving much attention by railway men, and that practical tests on a scale sufficiently large to enable definite conclusions to be made and opinions to be formed are now in progress in this country. Valuable results may be expected from these trials, and they will certainly tend to increase to a considerable extent the general interest which is felt by railway men in this subject. It is to be hoped that the results will be such as to lead to an extensive introduction of tested and approved forms of ties. It may be taken for granted that the tie adopted will be an American production and not an importation.

It is the object of this report to bring the matter clearly and fully before the practical railway men and railway financiers. It will, I think, show that the use of metal ties is not only in the interest of forestry and the preservation of the timber resources of the country, but is also in the interest of the railways by reason of the reduction in maintenance expenses and the increased safety in operation. The introduction of metal ties will therefore be for the benefit of the forests, the railway companies, and the public.

I am, sir, respectfully yours,

E. E. RUSSELL TRATMAN,
Jun. Am. Soc. C. E.

B. E. FERNOW, Esq.,
Chief of Forestry Division, Department of Agriculture,
Washington, D. C.

CIRCULAR.

The following circular was addressed to numerous railway companies, managers, and engineers in foreign countries, and also to manufacturers and others possessing information upon, or likely to be interested in, the subject of metal track for railways.

METAL TRACK FOR RAILWAYS.

The information outlined below is desired for the purpose of a report to the U. S. Department of Agriculture on the use of metal ties (sleepers) for railway tracks, and it is requested as a favor that all information furnished should be as complete as possible and sent at the earliest possible convenience.

Respectfully,

E. E. Russell Tratman, C. E.,
103 *Tribune Building, New York City, U. S. America.*

INFORMATION.

Railway:

1. Name.
2. Route.
3. Length of lines laid with metal ties (sleepers).
4. Character of same. (Particulars of grades, curves, etc.)
5. Dates when laid.
6. Engineer in charge.
7. Character of traffic.
8. Weight of locomotives and weight on driving wheels.

Tie (sleeper):

9. Longitudinal, transverse, or bowl.
10. General form.
11. Dimensions, including thickness. (Figured drawings.)
12. Weight.
13. Material.
14. Spacing, center to center.
15. How treated. (Paint, anti-rust process, etc.)
16. Manufacturer.
17. First cost, at factory or delivered.
18. Expense of maintenance.
19. Attachment of rails. (Details and drawings.)
20. Arrangements for curves.
21. Tie-rods; if used, how attached and adjusted for gauge.

Tie (sleeper)—Continued.

22. Durability.

Track:

23. Material of ballast.
24. Behavior of ballast under sleeper.
25. Construction of road-bed. (Drawing.)
26. Section and weight of rail.
27. Rail joints; how made.
28. Rail joints; on sleeper or suspended.
29. Reasons for adopting metal sleepers.
30. General results; satisfactory or otherwise.
31. Is there trouble with maintenance of track?
32. Is there trouble with rail attachments?
33. Is there trouble from breakages; how and where do they usually occur?
34. Efficiency, etc., as compared with wooden sleepers.
35. Cost, material, and durability of wooden sleepers.
36. Climate, and effect of same on metal or wooden sleepers.
37. General remarks.
38. Opinions.

Note.—The writer of this report will be pleased to be notified of any omissions or corrections, and to receive additional information, with drawings, reports, statistics, or other matter relating in any way to the general subject of this report. He will also be pleased to have correspondence with persons interested in the subject. All communications should be addressed to—E. E. Russell Tratman, C. E., Room 103, Tribune Building, New York City, U. S. America.

ERRATA.

NOTE.—Owing to the departure of Mr. Tratman for England before the report on Metal Track could be put into print, the proof-reading and the making of the index devolved upon the undersigned, both of which tasks have been very difficult on account of the exceedingly technical character of the report. There may be found, therefore, in addition to the errata below, others that have been overlooked, and the index may not prove so valuable as the author himself could have made it; any deficiencies in these respects the reader is asked to excuse and emend.

B. E. FERNOW.

Page 29, line 16 from top, read "Torley" for "Tooley."

Page 59, line 6 from top, read "designed" for "describes."

Page 59, line 12 from bottom, read "Greaves" for "Graves."

Page 65, after line 8 from bottom, add "some of the earlier Webb ties were made with closed ends."

Page 69, line 24 from bottom, the paragraph beginning "The track of this road" should have been set in the larger type, as it is not a part of the letter quoted in the two paragraphs preceding.

Page 70, after line 16 from top, add "Steel ties are said to be laid on the Harrow extension."

Page 70, line 24, beginning at "As regards maintenance" the remainder of the paragraph should have been set in the larger type, as it is not a part of the letter quoted immediately above.

Page 70, after line 3 from bottom, add "These ties are still in use."

Page 78, line 15 from bottom, read "had" for "have."

Page 86, line 7 from bottom, read "Fraisant" for "Fraisans."

Page 89, line 2 from top, read "designed by the engineers of the company" instead of "invented."

Page 91, line 13 from top, read "Contamin" for "Contannin."

Page 92, line 2 from bottom, read "cotter" for "cotler."

Page 95, line 5 from top; page 136, line 14 from top; page 145, line 13 from top and line 16 from bottom, read "Hoesch" for "Hosch."

Page 98, line 14 from top, and page 101, line 17 from bottom, ∩ should be used instead of ∧.

Page 117, line 1 from top, "I beam" should read "I-beam."

Page 166, line 9 from bottom, "28 inch thick" should read ".28 inch thick" and "36 inch thick" should read ".36 inch thick."

Page 181, line 7 from bottom, "34 miles" should read "30 miles."

Page 181, line 2 from bottom, "vertical 1 inch" should read "vertical for 1 inch."

Page 188, drop all Notes from "Being relaid, etc." to Note: "Ties in good condition," each one line. "Buckled steel" refers to Steel Ties only; "5 miles, etc.," refers to Vautherin ties only.

Page 205, line 19 from top, "for" should read "from."

Page 205, line 19, "The ties were made for plates" should read "The ties were made from plates."

Page 248, line 6, "4085 miles" should read "4.085 miles."

Page 256, line 14, "rig" should read "rib."

Page 262, line 1, "put up down" should read "put down."

Page 263, line 23 from top, "Cardova" should read "Cordova."

Page 286, line 19 from bottom, the brace used should have been as follows: ⏞

Page 318, "standard" should read "Standard."

Page 325, line 9 from top, for "railways will" read "railway ties will."

Plate VIII, first tie marked O should bear name "Cosijns type."

PART I.

USE OF METAL TIES ON RAILWAYS IN FOREIGN COUNTRIES AND IN THE UNITED STATES.

SECTION 1.—EUROPE.

ENGLAND.

GENERAL REMARKS.—The idea of using metal supports for railway rails was considered in the early days of railways. Mr. R. M. Stephenson, in his "Rudimentary Treatise on Railways," published in London in 1850, describes the five systems mentioned in the following paragraph:

Mr. Barlow describes a cast-iron combined longitudinal and chair which was tried on the Southeastern Railway. Each longitudinal stringer was in two pieces, with one side of the rail chair upon each piece; when put together, with the rail in place, a bolt (or two bolts at the joint chairs), was passed through the lower part of each chair, under the rail, holding the two pieces together. No transverse connections are mentioned or illustrated, but presumably tie-rods or bars were used. Mr. W. Brunton's track was very similar, but had a deeper web along the under side of the longitudinal, and the top instead of being longitudinal sloped upwards from the middle, forming a wide shallow V trough, with the rail along the middle. Mr. Graves' system consisted of two hollow cast-iron bowls in the shape of the frustum of a cone and connected by two tie-rods, one at the top and the other at the bottom of the bowls. A rail chair was cast on the top of each bowl, and the rails were keyed in the chairs in the usual way. Mr. W. H. Barlow patented a track with cross-ties bent up at the rail seats to fit the wide flanges of the Barlow bridge rail; another plan was to have a bridge rail bolted to a plate bent to the required form, and all bolted to the tie. Mr. Macdonald Stephenson's system consisted of kite-shaped plates of boiler iron one-half or five-eighths of an inch thick, with both ends turned up and notched to receive the rail. The rail joints were secured by a taper wedge or key driven between the rail and the side of the notch in the plate. The plates formed a continuous bed under each rail, and were connected at the rail joints by transverse tie-rods.

About 1853 iron longitudinals on the Macdonnell system were laid under the Brunel rails of bridge section on the Bristol and Exeter Railway (now a part of the Great Western Railway system), and in 1886 were reported by Mr. Walter Browne to be still in good condition. They were all out of the main track, however, in 1888. (See Great Western Railway.) Cast-iron bowls had been tried, experimentally, previous to 1877 on the Great Northern Railway and other lines running out from London. Within the present decade steel cross-ties have been tried on a number of roads, generally in connection with the standard English system of double-headed or bull-headed rails in chairs. No railway has really adopted steel ties, but Mr. Webb, of the London and Northwestern Railway, has laid down about 56 miles of his system at different parts of the line, and a few trial lots of the same system have been tried on other main lines, but only for experiment. A steel cross-tie with heavy steel rails of flange section is being tried on the Northeastern Railway, and this experiment is of special interest, as the type of track is similar to that which would probably be used in this country should steel ties be introduced, and as it is under severe conditions of traffic its behavior will be some guide for American railway engineers. An English engineer writing to me in December, 1888, on this subject, made the following remarks:

> The chief difficulty is in the adaptation of the steel sleepers [ties] to the double-headed rail, as it does not make a good job, although perhaps Mr. Webb would say to the contrary. The steel sleeper is essentially a sleeper for flat-bottomed [flange] rails, and until our railway companies alter their rails I do not think steel sleepers will come into general use. The Northeastern Railway Company is now trying 3 or 4 miles with a flat-bottomed rail on a steel sleeper, and there appears some promise in this, but it will take years to convert English engineers to the steel sleeper; there are some conditions of traffic opposed to it, as well as the satisfactory experience with our present system.

With the English system of track, the rails are supported in cast-iron chairs, weighing from 20 to 56 pounds each, placed one at each end of every tie, and this practice tends to reduce very greatly any cutting of the tie, as the weight coming upon the rail is distributed over an area of about 7 by 12 inches, or 7 by 15 inches, so that the ties can be counted upon to last out their natural life; while in this country the flange of the rail, 4 to 5 inches wide, cuts into the ties, so that they have often to be taken out before decay has commenced. It may be mentioned, however, that metal tie-plates are now being introduced here to reduce this cutting of ties. English track, therefore, with preserved ties and a broad surface to carry the loading, is very economical in maintenance, and Mr. Owen, the engineer of the Great Western Railway, stated in September, 1889, that as long as creosoted timber ties can be obtained at anything like the present prices, there is no probability of metal ties being generally adopted on English railways. The life of wooden ties used in England is estimated at from eight to thirty years. Descriptions and illustrations of the track on different roads may be found in my paper on "English Railway Track" (Transactions of the American Society of Civil Engineers, New York. June, 1888).

The manufacture of metal ties is a very large industry and is carried on by a number of the most important steel works and foundries. Up to 1888 about 525,000 tons of steel ties had been manufactured, and about 70,000 or 80,000 tons have been turned out since; most of these are for India, with a few hundred tons for railways at home and in other countries. Very large quantities of cast-iron ties have also been manufactured for export, principally plates and bowls for India and bowls for South America. Up to June, 1888, about 2,000,000 pairs of plates for double-headed rails and 600,000 pairs of plates for flange rails, had been supplied for railways in India.

NORTHEASTERN RAILWAY.—Some years ago several steel ties of the type designed by Mr. Charles Wood, of Middlesborough, were tried for about two and a half years, under the supervision of Mr. Cudworth, the engineer. It is stated that the results were not very satisfactory, as the ties cracked where pierced for the fastenings, and the fastenings themselves were very liable to wear. (See Wood's Ties.) I was informed in July, 1889, that they had all been taken out some time since. The ties were of inverted-trough section; the fastenings consisted of a crescent-shaped piece of steel, with the ends projecting up through holes in the tie; one end was shaped to hold the rail-flange and the other end extended nearly to the height of the rail-head, a wooden key being driven between it and the web of the rail. Some steel ties of the type designed by Mr. Webb, of the London and Northwestern Railway, have been in service on the Stockton and Darlington section, and on a piece of track north of Ferryhill. In July, 1889, they had been in service about four and a half years, and had given satisfactory results, but having riveted jaws or chairs they were of course expensive.

In 1887 an experiment was begun with some steel ties designed by Mr. Cabry, the chief engineer, and Mr. Kinch, one of the resident engineers. (See Plate No. 1.) About 10,000 of these ties are now in service on the Central Division, and on the main line on the Northern and Southern Divisions, where the traffic is heaviest and where the trains run at the highest speeds. Under these conditions they have given such excellent results that in July, 1889, the directors of the company, so I am informed, ordered a further supply. One of the most noticeable features of this track is, that steel flange rails, weighing 91 pounds per yard, are used instead of the double-headed or bull-headed rails generally used on English railways. The tie is stamped out of a steel plate and is of inverted trough section with a very narrow flange or rib on the lower edges, being a modification of the Vautherin type of tie. The ends are open. It is 8 feet long, 8 inches wide on top, 3½ inches deep, and 12 inches wide at the bottom. It is of uniform section throughout, with a uniform thickness of three-eighths of an inch. Its weight is 150 pounds. In the operation of stamping, the part under each rail is pressed up at an angle to give the rail the usual inward inclination of 1 in 20. At the same operation four pieces are pressed up out of the metal at each rail seat; three of these are on the outside of the rail, one forming a clip or jaw to hold the rail-flange, the other two being studs against which the rail-flange abuts and which keep the gauge exact; the fourth projection forms a jaw to hold the inner flange of the rail. The jaw on the outer side is 2½ inches wide and bears five-eighths of an inch in upon the rail-flange; the jaw on the inner side is 3½ inches wide and projects about three-eighths of an inch over the rail-flange but does not touch it, leaving space for the steel wedge or key to be driven tightly between the jaw and the rail-flange. The keys are tapering, 8 inches long, are split at the smaller end, and weigh 1½ pounds each. In the track the ties are spaced eleven to a rail length of 30 feet, averaging 2 feet 8¾ inches from center to center. It is said that they compare favorably in cost with the present system of wooden ties and cast-iron chairs, and it is expected that by their use the cost of maintenance of the track will be materially reduced. In July, 1889, they had been in service for eighteen months, and had given very satisfactory results. Their maintenance had given no trouble, and the cost of maintenance was as nearly as possible the same as that of track on wooden ties. The ties are manufactured by Messrs. Bolckow & Vaughan, of Middlesborough, and some of them have been sent to Italy to be tried as an experiment. They were patented in the United States, November 13, 1888 (No. 392,849).

The rails are of flange section, weighing 91 pounds per yard; they are 5⅛ inches high with a flange 5½ inches wide and a head $2\frac{9}{16}$ inches wide. To put a rail in position it is tilted slightly and the inner side of the flange slipped under the inner jaw, sufficient space being then allowed for the outer side of the flange to clear the outer jaw; when on its seat the rail is slid under the outer jaw and the key driven on the inner side of the rail. As the rail-flange is overlapped by both jaws, it cannot be forced out of them by the side pressure of the wheels of trains even if the keys are displaced, though it might be tilted over a little. The heaviest engines in use are tank engines, with a wheel-base of 22 feet 6 inches; they weigh 55⅗ gross tons and have 16¾ tons on the driving-wheels.

The following tables, prepared by Mr. Cabry, the chief engineer, and Mr. Worsdell, the locomotive superintendent, in December, 1888, show the cost of the track with flange rails on steel ties and the cost of the ordinary track laid with bull-headed rails in cast-iron chairs on wooden ties. Both are exclusive of ballast. I have reduced the figures to American money.

Statement of cost of 1 *mile of single track on steel ties.*

Materials.	Numbers.	Weight.		Rate.	Amount.	Total.
		Tons.	*Lbs.*			
Steel flange rails, 90 pounds per yard	....	141	960	$19.37½	$2,740.18	
Fish-plates, 13 pounds each	704	4	192	28.75	117.46	
Fish-bolts and nuts, 1½ pounds each	1,408		2,112	41.92	39.61	$2,897.25
Steel ties, 150 pounds each	1,936	129	1,440	23.75	3,079.00	
Steel keys, 1½ pounds each	3,872	2	1,328	55.00	142.60	3,221.60
Carriage of materials	....	274	1,860	1.25	343.53	
Storage and incidental expenses	....	274	1,860	.25	68.71	
Use of locomotive in distributing materials on the line, at, say $75 per mile	....	......	......	....	75.00	
Labor of laying, cubic yards	1,760	......	......	.25	440.00	927.24
Cost per mile	....	......	......	....	....	7,046.09

Statement of cost of 1 *mile of single track on wooden ties.*

Steel bull-headed rails, 90 pounds per yard	....	141	960	$19.37½	$2,740.18	
Fish-plates, 13 pounds each	704	4	192	28.75	117.46	
Fish-bolts and nuts, 1½ pounds each	1,408		2,112	41.92	39.61	$2,897.25
Chairs, 40 pounds each	3,872	69	320	13.12½	907.50	
Keys	3,872	......	......	9.37½	36.30	
Spikes, 22 ounces each	11,616	7	292	33.61	239.65	
Creosoted wood ties	1.936	......	......	.62½	1,210.00	2,393.45
Carriage of materials	....	352	836	1.25	440.46	
Storage and incidental expenses	....	352	836	.25	88.11	
Use of locomotive in distributing materials on the line, at, say $75 per mile	....	......	......	....	75.00	
Labor of laying, cubic yards	1,760	......	......	.25	440.00	1,043.57
Cost per mile	....	......	......	....	....	6,334.27

SUMMARY OF STATEMENTS OF COST.

	Track on—		Difference.
	Steel ties.	Wooden ties.	
Cost per rail length, 30 feet	$40.03	$35.98	$4.05
Cost per yard	4.00	3.59	.41

London and Northwestern Railway.—Experiments with steel ties have been made on this road during over nine years and on a fairly large scale. Particulars of the experiments have been published from time to time, and the trials are given considerable prominence in discussions on matters relating to metal track. The ties are of a form designed by Mr. F. W. Webb, the mechanical superintendent of the line; they are of the familiar inverted-trough section, with small flanges on the bottom edges, and are of uniform section and thickness; they are a modification of the well-known Vautherin type. (See Plate No. 2.) They were first laid in August, 1880; in 1885 there were 32,174 in service; in June, 1886, there were 55,000 in use on this road in addition to trial lengths on other English lines; in 1888 there were 83,204 of these ties in service, and the road had between 20 and 30 miles of track laid with them; in November, 1889, Mr. Webb stated that there were then 56 miles of track and about 100,085 ties in use. They are of rolled steel, five-sixteenths of an inch thick; length, 9 feet; width on top, 6 inches; width at bottom, 11 inches; depth, 2½ inches; weight, 136 pounds each. The rails are of bull-headed section weighing 84 and 90 pounds per yard, the latter being now the standard rail. The chairs, instead of being of cast-iron, are made of three pieces of steel, rolled and stamped to shape from plates one-half an inch thick made from the crop ends of rails; one piece forms a tie-plate 15 by 6 inches, five-sixteenths of an inch thick, with the middle part bent to fit the bottom of the rail and give the inclination of 1 in 20; the other pieces are one-half an inch thick and form angle brackets, the inner one fitting the web and lower head of the rail, and the outer one being placed so as to allow of a wooden or steel key being driven between it and the web of the rail. The steel key has a projection which fits into a vertical groove in the chair, so that it cannot work loose. A liner of brown paper or canvas soaked in tar is sometimes interposed between the angle-pieces and the tie-plate and between the tie-plate and tie. The chairs are fastened to the tie by six three-quarter inch rivets, three on each side of the rail, passing through the angle-pieces, tie-plate, and tie; the rivet-holes are punched in a hydraulic press. The ties and chairs are made and fitted complete at the railway company's works at Crewe, and the cost is said to compare favorably with that of the ordinary system of cast-iron chairs weighing 45 pounds each, spiked and screwed to wooden ties 10 by 5 inches. This may be so in this case, where everything is done in the company's shops, and where the ordinary track is of an expensive character, but if made under contract for orders, the amount of shop-work required would probably make the finished tie very expensive.

With these steel ties the distance from the bottom of the tie to the top of the rail is $8\frac{3}{16}$ inches, while with the wooden tie it is 12⅛ inches. The ties are covered with ballast, which is brought nearly up to the level of the top of the rail head on the outside of the track and between the rails it is about 2 inches below the top of the rail head. It has been said that the ballast would be less affected by frost at a depth of 5 inches, where the wooden ties rest, than at 2½ inches where the steel ties rest; but this is probably of little practical account. The reduced depth of the tie of course effects a saving in the quantity of ballast. The ties are spaced 3 feet apart center to center.

The following is a comparison of the two systems, column A being for track on steel ties and column B for track on wooden ties:

London and Northwestern Railway.	A.	B.
Ties:		
Length .... feet..	9	9
Breadth .... inches..	11	10
Depth .... do....	2½	5
Thickness .... do....	$\frac{5}{16}$	.....
Chairs:		
Length of bearing on tie .... inches..	15	14⅜
Width of bearing on tie .... do...	6	7¾
Area of bearing on tie .... square inches..	90	111
Weight of one tie complete:		
Two chairs .... pounds..	48	90
Fastenings, liners, etc .... do....		12
One tie .... do....	136	140
Total .... do....	184	242

The ends of the ties are open, but it is claimed that no trouble has been experienced from lateral motion or shifting of the track when properly ballasted, although some have been in use in the South Wales district on curves of 660 feet radius on a grade of 1 in 38.

It is not stated, however, whether the entire curve was laid with these ties or whether only a few were laid for trial. In the latter case there might have been sufficient wooden ties to hold the track in place. Considering that wooden ties are found to shift in the track in some places, it seems only reasonable to provide at least as much end bearing or area for metal ties as for wooden ties, especially on lines where there are many curves. Mr. Bricka, engineer-in chief of the French state railways, in his report on metal track, made to the minister of public works in 1886, attributes this freedom from lateral motion to the rigidity of the heavy rails, to the slight lateral play of the cars, and to the use of locomotives with inside cylinders and running gear. He saw the ties in use on tangents and flat curves, but thought they would shift on sharp curves. In view of extensive experience on other lines, he considered that the ends of metal ties should be closed. This is the generally accepted conclusion.

The traffic is very heavy as regards the number and speed of trains. The heaviest main-line engine weighs 95,200 pounds, on six wheels, and the heaviest load on any one pair of driving-wheels is 33,600 pounds. Mr. Bricka, in the report above mentioned, refers to this heavy traffic, and states that on one section there were twenty-four express trains per day, often running at nearly 60 miles an hour, besides numerous freight-trains. He says the ties were first made of wrought-iron, but later of Bessemer steel non-dephosphorized. Some ties of harder Bessemer steel, made by the acid process, cracked through the rivet holes and some of the steel-plate chairs also cracked through the holes. Some cast-iron chairs had also been tried. There were in service at the time of his visit 30,000 ties, of which 18,000 were in the main track. He gives the cost of a steel tie as $2.50 and of a creosoted pine tie $2.10, including chairs and spikes complete. The steel ties are dipped hot in tar and then in sand, to increase the adhesion in the ballast. Nevertheless considerable trouble was experienced from rusting, which Mr. Bricka attributes to the use of slag and cinders for ballast. The sulphur, being kept damp by the climate, produces a chemical action similar to that observed in tunnels. In Holland and Belgium, however, no trouble has been experienced from rusting, even in cinder ballast.

These ties, with the English rails and chairs complete, have been tried experimentally in this country on the Pennsylvania Railroad.

MIDLAND RAILWAY.—In 1885, 250 tons of steel ties were rolled by the Cockerill Works, in Belgium, for this line. (See plate No. 3.) These ties were designed by Mr. A. Langley, chief engineer of the road, who has stated that they answer very well, but that the cost as compared with that of wooden ties is against them. In July, 1889, Mr. Langley stated that about 10,000 steel ties were then in the track, but that their use was not being extended. They have proved efficient in service and the maintenance is practically the same as with the creosoted wood ties. The steel ties are of inverted trough section, with a narrow flange on the bottom edges, and have the ends flared out and bent down. The closed ends prevent lateral motion and also prevent any tendency of the sides to spread. The ties are 8 feet long over all, 8 inches wide on top, 3 inches deep, 13 inches wide over all at the bottom. They are of uniform thickness and section throughout, the thickness being five-sixteenths of an inch. The weight is about 132 pounds each and the cost $1.76 each. The joint ties are spaced 2 feet 2 inches apart, center to center, and the intermediate ties 3 feet apart. The ties are rolled from steel which is specified to be of such quality and temper that it will not crack or split when stamped or rolled to shape. The holes may be punched or drilled according to the engineer's approval. The ties are not tarred nor painted, but are given one coat of linseed oil, laid on hot, at the works.

On each tie there are two cast-iron chairs weighing 40 pounds each (pattern of 1885), each chair being secured to the tie by a pair of patent steel twin bolts of ⊔ shape, seven-eighths-inch diameter, with four lock-nuts. The bolt-holes in the ties are fifteen-sixteenths inch diameter, 3¼ inches from center to center crosswise, and 11 inches from center to center lengthwise of the tie, the inner holes being four feet five-eighths of an inch apart center to center. The base of the chairs is 7¾ by 14 inches, and a felt pad one-eighth of an inch thick is placed between the chair and the tie. The rails are of bull-headed section, weighing 85 pounds per yard, and are fastened in the chairs by wooden keys. The wooden ties weigh about 134 pounds each. The weight per yard of the ordinary track is estimated as follows: Steel, 170 pounds; wrought-iron, 14.9 pounds; cast-iron, 110 pounds; wood, 151.9 pounds; total, 446.8. The weight of the heaviest engine is about 78 tons in working order, and the number of ordinary trains in twenty-four hours is two hundred and thirty, exclusive of special trains, light engines, etc.

At the International Railway Congress, held at Milan, Italy, in 1887, Mr. Kowalski stated in regard to this road that there were 10,000 ties of the form designed by Mr. Langley, being a modification of the Vautherin type, but that the experience with them only dated from January, 1886, and, therefore, no definite opinions could be given as to the results.

A few of the Tozer steel ties have been laid as an experiment. (See Tozer ties.)

GREAT NORTHERN RAILWAY.—Mr. T. H. Horn, assistant engineer, stated in December, 1888, that the experience with metal ties on that line was so limited that no results could be given which would be of service. Short lengths of several types had been laid down experimentally, but altogether there was not then a mile of track on which metal ties had been introduced. The first cost, as compared with that of ordinary fir ties with chairs and fastenings, tells against them. The ties of the Howard type for main lines were of inverted trough section, with a deep depression at each end, forming a seat for the bull-headed rails, which were secured by keys in the usual way. (See plate No. 4.) These ties were 8 feet long and weighed 140 pounds each; they were made from plates of Siemens steel three-eighths of an inch thick. (See Howard ties.) The track of this road is laid with steel rails of bull-headed section, weighing 82 pounds per yard.

At the International Railway Congress held at Milan, Italy, in 1887, the following particulars in regard to this road were presented by Mr. Kowalski:

> About 1,000 ties were in service, and four types were being tried, Webb, Moss-Bay Company, Howard, and Tozer. All were of steel. The Webb ties weighed 176 pounds each, complete; the Moss-Bay and Howard ties 139.5 pounds, and the Tozer ties 137.5 pounds, exclusive of the fastenings. They were all laid on embankments, and were on tangents. The traffic consisted of passenger and freight trains running at reduced speed. The weight of the engines was about 60 to 70 tons. The ballast was mainly of gravel. The first cost of the track appeared to be three times as great as that of track with wooden ties, but the experience was too short for any judgment to be formed as to the cost of maintenance and the durability. The elasticity of the track and the easy riding of the trains were the same as with ordinary ties. The inconveniences were in the difficulty of attaching the several pieces to the body of the tie, and in case of derailment the ties would probably be damaged. The company had at that time no intention of extending the use of metal ties on its road.

The following report on the Howard tie was made in February, 1887, by Mr. Bastin, and was published in The Indian Engineer, of Calcutta, March 31, 1888:

> On the 7th instant I arrived at Holloway Station, on the Great Northern line, to inspect the Howard steel sleepers (ties), which I superintended the laying of in May of last year. After the ballast had been cleared away I made a thorough examination of them, and am pleased to report that they are in as good condition as when they were laid down. The ganger over this portion of the line informed me that the sleepers had not required any attention whatever since they were laid down: the ballast had not been touched nor had the keys had a hammer upon them. They were purposely laid upon a part of the line over which the most and the heaviest of the traffic passes, so that with such an amount of traffic and the long and severe frost they had been well tested. I also examined some other steel sleepers, laid side by side of the Howard sleepers. These other sleepers are trough-shaped, with cast-iron chairs bolted to them, the ends of the sleepers being turned down. These sleepers are like the Belgian type on the Midland line near Bedford, and, like them, they had shifted endways; and after the frost went they had to be reballasted. I have been to see the sleepers on the Midland line again to-day, Belgian type, and although they were reballasted after the frost they have again shifted so that the line is not perfectly true, the want of straightness being quite obvious.

GREAT WESTERN RAILWAY.—About 1853 the Macdonnell system of track, with metal longitudinals, was introduced on the Bristol and Exeter Railway (now the Bristol and Exeter division of the Great Western Railway), and in August, 1889, the resident engineer reported that the last of it had been taken up only about twelve months previous. This gives some idea of its life, and it must be borne in mind that it was in use under very heavy traffic. The ordinary track of this line was built on the plan designed by Mr. Brunel for the Great Western Railway, and consisted of rails of bridge section secured to wooden longitudinals, which were connected at intervals by wooden transoms. The gauge was 7 feet. The Macdonnell track consisted of iron longitudinals; the plates were a little over 1 foot wide, about one-half an inch thick under the rail, and five-sixteenths of an inch thick at the edges. In the middle, on the upper side, was a rib about 2 inches high, fitting into the hollow of the rail. On each side of the rib was a wooden packing half an inch thick and about 2½ inches wide, upon which the rail flanges rested. A shallow rib on each side, about 2½ inches from the middle rib, held the wooden packing in position. The rails were fastened by bolts passing through the plate, packing, and rail flange, the nuts being screwed down on the flange. In some cases the plates were flat for their entire width; in other cases they were slightly curved down, outside the outer ribs, to a depth of about three-fourths of an inch. The plates were connected at intervals by transverse T irons. The rails were about 3 inches high, 2⅝ inches wide, and 6 inches wide over the flanges; the middle space or groove was about 2 inches deep, ¾ to 1 inch wide. This form of rail is still in use. The resident engineer stated that while he could not recommend the Macdonnell system for main track, it may be very serviceable for light railways or for side tracks; he has used it and is still using it for the latter purpose. The main objection to it is said to be the difficulty in keeping the rails tight upon it, and the number of bolt-holes weakens the plates so much that they were continually breaking, especially near the rail-joints. Another objection is, that "in very hot weather the expansion is so great as to displace it several feet from its proper position." In 1886 this track was reported by Mr. Walter Browne to be in good condition.

The Tozer ties have been tried, but Mr. Lancaster Owen, chief engineer, stated in September, 1889, that only a few ties of this type have been put down, and only as an experiment.

London and Southwestern Railway.—Mr. Andrews, the chief engineer of the road, writing in August, 1889, stated—

> The experience with metal ties on this line is very limited. About four years ago a few were laid down and are still in service. They were pressed out of mild steel plates about five-eighths of an inch thick, and were of inverted channel form, with cast-iron chairs secured to them by wrought-iron bolts. When they were laid considerable time and trouble was expended in thoroughly filling them and packing them with gravel ballast; but now that the track has become consolidated, they do not require much more attention than timber ties. The chairs, however, break more frequently than on wooden ties, and the bolts require frequent attention.
>
> The wooden ties used are of redwood fir, obtained from the Baltic, and in view of the number available, the facilities for obtaining them, and the price paid, it is not considered that the company can do better than continue to use them. The company creosotes its ties, and the value of a creosoted tie is about 78 cents, delivered. Jarrah and other hard-wood ties from Australia have been offered at different times, but their high cost, delivered in England, prohibits their adoption, even though, as is urged, they would last much longer than the Baltic fir ties.
>
> The track of this road consists of double-headed steel rails, 30 feet long, weighing 82 pounds per yard; they are 5¼ inches high, with heads 2¼ inches wide. They are secured by wooden keys in cast-iron chairs, weighing 40 pounds each, which are fastened to the wooden ties by three round spikes driven into hollow tree-nails; the chairs have a base of 6¼ by 14 inches. The rail joints are even and suspended, and are spliced by deep fish-plates, with four bolts. The wooden ties are 9 feet long, 5 by 10 inches section; they are spaced 2 feet 2 inches apart, center to center, at the joints, 2 feet 5 inches next to the joints, and 2 feet 10½ inches intermediate. In 1890, rails weighing 87 pounds per yard and chairs weighing 45 pounds each are to be used.

London, Chatham and Dover Railway.—Mr. William Mills, chief engineer, stated in August, 1889:

> No metal ties are used, for the reason that the creosoted ties are found to last, in a general way, as long as the rails, and it is to the company's interest to renew both rails and ties at the same time. The line passes through a brick-making locality, and has the advantage of being able to sell the bulk of its old ties at about half their original cost.

Probably very few railways are able to dispose of their old wooden ties to such advantage, and in many cases in this country it is not easy to get rid of them except by burning. As regards renewals, it would seem to be still more to the company's interest to have ties which would not have to be renewed as often as the rails, especially as the present system of track is already an expensive system to build, so that the increased cost for metal track would be comparatively small.

LONDON, BRIGHTON AND SOUTH COAST RAILWAY.—Mr. F. D. Banister, chief engineer, stated in August, 1889:

> The only experience with metal ties on this line has been a small trial, which was unsatisfactory; and the result was not sufficient to warrant any departure from the general system of using Baltic fir ties, creosoted by Brystie's process.

METROPOLITAN RAILWAY.—This is one of the city (underground) and suburban railways of London, the traffic on some sections of which is very heavy and is carried on under exceptional conditions. Mr. J. J. Hanbury, resident engineer, states:

> A trial has been made with twelve steel ties of the Tozer type; they were in service about two years, at the end of which time it was found that the chairs began to work a little, owing to the wear of the stud which fits into a hole in the tie. (See plate No. 4.) These ties were considered to be unsuitable for this road. Some steel trough ties, similar to those of the Midland Railway, but weighing 145 pounds each, have been tried; they were made by the Tredegar Iron and Coal Company. The rails used are of double-headed section, carried in cast-iron chairs bolted to the ties.

METROPOLITAN DISTRICT RAILWAY.—This is another of the city (underground) and suburban railways of London. Mr. George Estall, engineer and locomotive superintendent, stated in October, 1889:

> Steel ties of the Tozer type have been tried on this road for a length of about 30 feet; they are laid in a locomotive yard. on the level, and are spaced 2 feet 8 inches to 3 feet apart, center to center. They were not painted or otherwise treated. The ballast is of gravel. They were laid for trial only, and the results have not been sufficiently satisfactory to lead to their adoption; as regards maintenance, rail attachments, and general efficiency, they are said to be inferior to timber; they are also too rigid, and are bad for packing. Mr. Estall is not in favor of their use. No breakages have occurred. The wooden ties used are of Memel fir, creosoted; they cost $1.50 each, and last fifteen years. The rails are of bull-headed section, weighing 87 pounds per yard, laid with suspended joints, and supported in cast-iron chairs in the usual way.

MERSEY RAILWAY.—This is a tunnel line, connecting Liverpool and Birkenhead. Mr. C. A. Rowlandson, resident engineer, stated in July, 1889, that about a dozen steel ties of the Tozer type had been tried, but only on a side-track. They have, however, stood very well as regards freedom from corrosion by the ash ballast and in keeping their level or surface.

GREAT EASTERN RAILWAY.—Some steel ties have been in use on this road for several years. They are of the inverted trough section, with closed ends, and the rails are carried in cast-iron chairs of the usual form fastened to the tie by a pair of twin bolts. They are 8 feet long, and were manufactured by the Darlington Steel and Iron Company. At the International Railway Congress held at Milan in 1887, Mr. Kowalski stated that a trial was being made with 500 ties, and that 4,000 were to be laid. The experience with them was then too short to enable any opinions to be given.

FURNESS RAILWAY.—In August, 1889, Mr. F. Stileman, chief engineer, stated:

A few years ago a trial was made with some steel ties of the Howard type (see plate No. 4); they were of inverted trough form, and of arched section; a deep depression at each end formed a seat for the rails, which were secured by keys in the usual way. It was found, however, that with keying the rail up the ends of the tie were sprung, and in the course of four or five months, with the traffic passing over, the ties split so that they had to be taken out. They were of steel and were shaped cold, the recesses for the rails being stamped by hydraulic machinery. (See Howard ties.)

The company now uses none but wooden ties, 9 feet long, 10 by 5 inches section, sawn out of timbers 9 feet by 10 inches by 10 inches. After being dried they were creosoted, which cost about 16 cents per tie. Their life will average from twelve to fourteen years. The chairs have a base of about 15 by 7½ inches and weigh nearly 50 pounds each. The rails are of bull-headed section, weighing 84 pounds per yard; they are fastened in the chair by oak keys, scalloped out in the middle, with a saw-cut at one end, which enables the end to close when being driven and to open out when in place.

North Staffordshire Railway.—A steel tie has been tried at Stoke-upon-Trent, on this road, and in January, 1890, after two years' experience, a large order was given to the Chair and Sleeper Company for these ties, which are described further on. The ties were of V-section, with ordinary cast-iron chairs secured to the flanges.

TIES.

The Livesey Ties.—A number of different forms of metal tracks have been designed by Mr. James Livesey, of London, and have been extensively used, especially in South America, by Mr. Livesey and other engineers. (See India and South America; and Plates Nos. 20 and 26.) The types most used are those consisting of bowls and tie-bars. Among the principal forms are the following:

(1) Cast-iron bowls, arranged in pairs and connected by transverse flat wrought-iron tie bars. The bowls are oval in plan, and the upper part forming the chair can be adapted for double-headed or flange rails. Two fixed clips hold the outer side of the rail, and on the inner side is a flexible jaw let into a socket and having a key driven between it and the rail.

(2) Wrought-iron bowls, also arranged in pairs and connected by tie-bars. They are practically rectangular on the bottom and oval on top, shaped like a dish-cover. They are adapted for flange rails. The fastening consists of a steel strip, of ⌟ shape; the longitudinal leg is within the bowl and is secured by a bolt, the washer of which holds the outer flange of the rail; a metal key is driven between the rail and the upright leg, which is inclined inward.

(3) Wrought-iron cross-ties. These are of inverted trough section, being a modification of the Vautherin type; some of these have horizontal flanges on the lower edges. The ends are closed and rounded off, and project deeper into the ballast than the body of the tie. The fastenings consist of two riveted clips, one bearing on the outer flange of the rail and the other projecting over the inner flange, with a key driven between the clip and the flange. A fastening similar to that of No. 2 may also be used.

(4) Steel cross-ties. For meter gauge lines these ties are 5 feet 6 inches long over all, 10 inches wide at the bottom; 5¼ inches wide on top, with rounded corners and curved sides. The ends are curved down. Thickness, seven-thirty-seconds of an inch throughout. Each rail rests on a tie-plate 9½ by 5 inches in size, seven-sixteenths of an inch thick, which is fastened to the tie by two rivets three-fourths of an inch in diameter. There are two jaws about 3 inches long, pressed up out of this plate; the outer one holds the outer rail-flange, and a corrugated key 6½ inches long is driven

between the inner jaw and rail flange. The tie is bent at the rail seats to give the rails an inward inclination. These ties are similar to the steel ties on the Indian State railways.

The Tozer ties.—Messrs. J. and H. Tozer of London, manufacture steel ties which are fitted with chairs for double-headed or flange rails. They are of inverted trough form, rounded in section, and deeper than is usual. (See plate No. 4.) For standard gauge lines the ties are 8 feet long, 9 inches wide on the bottom, and 4⅛ inches deep. The sides are about one-fourth of an inch thick and the top three-eighths of an inch thick. The ends are bent down and flared out at the corners; the tie is bent from the middle to give the rails the inward cant of 1 in 30. For flange rails a flat chair is used 9¾ by 4 inches, having two jaws, one of which grips the rail flange, while a key is driven between the other jaw and the flange; the thickness is three-fourths of an inch under the rail. On the bottom of the chair is a pin or stud, which engages with a hole in the tie and prevents spreading of the track; in setting the chair, it is placed on the tie at right angles to its normal position, with the stud in the hole; it is then turned round into position, the ends of the chair passing under jaws or lugs pressed up out of the metal of the tie; the chair has stops at diagonally opposite corners, to prevent it from being turned beyond its proper position. The rails are then laid and the keys driven, after which the chair cannot shift in either direction. The chairs and ties are made to give an exact gauge of 4 feet 8½ inches, but in order to allow for widening the gauge at curves the chairs are so arranged that by reversing one and inserting it in the opposite direction under the lugs the gauge will be widened half an inch, while by reversing both of them the gauge will be widened 1 inch. To give this adjustment the keys must be always on the outside of the rails. If keying on the inside is practicable, the gauge may be also increased by reversing one or both of the chairs and keying one or both of the rails on the inside. The several increments of widening of the gauge are thus as follows: ½, ⅝, and 1 inch; 1⅛, 1¼, 1⅝, 1¾, and 2¼ inches. The weights are as follows: steel tie, 93 pounds; two cast-iron chairs, 18 pounds; two steel keys, 1½ pounds; total weights 112½ pounds. A steel chair is also used, riveted to a steel tie five-sixteenths of an inch thick. The ties are of Bessemer steel and are dipped in a preservative solution. Their cost, as quoted in March, 1888, was about $26.25 per ton, free on board. For double-headed rails the only difference is in the form of the chairs, which are of the usual shape, with high sides to hold the rail and the wooden or metal key; but with the addition of the round stud on the bottom and the stops to keep the chair in place. Small trial lots have been used on several English railways, a few have been sent to China, and 365,000 (20,000 tons) to the Argentine Republic. The advantages claimed are the broad surface of the chairs to distribute the load over the tie, the reduction in the number of loose parts, and the adaptation to present tracks with double-headed or bull-headed rails. The lugs which hold the chairs in place have a good holding-down power, but are claimed to be elastic; so that while giving a firm grip in the chair they render it less liable to fracture than by being held too rigidly.

The Kerr and Stuart ties.—Messrs. Kerr and Stuart, of London, manufacture a variety of steel ties of different forms for permanent and light railways, portable railways, and street railways. Their special patent type is a steel cross-tie of inverted section, bent up at the ends to give the rails an inward inclination of 1 in 20. The ends are closed. These ties are for flange rails. The outer flange is held by a riveted jaw or brace, which projects upward and bears against the under side of the rail head. The inner flange is held by a bolted clip, the lower part of which fits into a T-shaped slot in the tie; a steel cotter locks the bolt and clip in position. (See plate No. 4.) The ties are all of mild steel, made by the Bessemer or basic process, rolled in lengths, sheared off, and stamped while hot. The clips are of steel, stamped by hydraulic pressure. This system of tie and fastening is also applied to girder rails for street railways. Following are the particulars of some of these ties: For 2 feet gauge, 4 feet long, costing 96 cents each; for meter gauge, 5 feet 4 inches long, costing $1.20;

for standard gauge, 6 feet 8 inches long, costing $1.56; for the Indian gauge of 5 feet 6 inches, 7 feet 6 inches long, costing $1.86. This tie is considered by the manufacturers to be especially adapted to very narrow gauges, such as 24 inches, on account of the firm support of the rail by the outer brace; it is used for a line of this gauge in Venezuela. Other forms of trough ties are made with different systems of fastenings. One fastening consists of a clip holding the outer flange of the rail, and a gib and cotter on the inner side. Another fastening (Walker & Bear's patent) consists of two loose clips; a small clip or gib holds the inner flange of the rail, and a larger clip on the outer side has a wooden key driven between it and the rail. Steel cross-ties of the pattern of the Indian State Railways are also manufactured, and have been supplied to the Morvi Railway in India. These are of rounded trough section, with the rail seats inclined 1 in 20 and the ends closed and curved down. At each rail seat are jaws to hold the rail, which is fastened by a steel key.

The ties are rolled with the metal of the top thicker than the sides and they are afterwards pressed to shape by hydraulic pressure, and the clips punched out and bent. The following are the particulars of some ties of this type:

Gauge.		Weight.	Length.		Price, complete with keys.	Suitable for rails weighing per yard—
Ft.	*In.*	*Pounds.*	*Ft.*	*In.*	*Dollars.*	*Pounds.*
2	6	35	4	6	0.69	25 to 30
3	3⅜	65	5	4	1.02	40 to 60
4	8½	80	6	9	1.32	60 to 80
5	6	95	7	6	1.56	60 to 80

The Howard ties.—The steel ties manufactured by J. and F. Howard, of Bedford, for main lines, are of approximately semi-circular cross-section, of different dimensions and section at different parts of their length. (See Plate No. 4.) Each tie is made from a steel plate pressed to shape by hydraulic power. The rail seat for double-headed rails is a depression in the tie deep enough to admit the web and lower head of the rail, which is secured by a wooden key driven between the web and the side of the depression in the tie. No bolts or rivets are used. These ties were patented in the United States December 22, 1885 (No. 333,015). In July, 1889, the firm reported that the manufacture of ties for main lines had not been commenced on a large scale, but that trial lots had been supplied to a few lines (see Great Northern Railway and Furness Railway). In March, 1888, special plant for making ties was patented in England. The plate of each tie is rolled so that the portions where the rail recesses are to be formed are left thicker, the trough formed on the under side by the corrugation being filled up or partially so, or the raised portion may be left solid throughout the length of the tie. The rail recesses are partially formed by the rolls which produce the plates, and for this purpose depressions are formed upon the periphery of one roll and corresponding indentations upon the periphery of the other roll; so that the plates in being rolled are indented at the parts where the recesses are to be formed. The plates are then passed through rolls with similar projections and indentations, which give the plates their finished form. The plates are passed between these rolls as they leave the plate rolls and while still hot, and are subsequently shaped by suitable presses. The rail recesses are finished to the proper shape by cutting appliances, consisting in the use of an endless or revolving table composed of a number of links or small platforms carried upon wheels. The plates are placed upon these platforms, and as the table moves forward they are caused to pass under a number of cutters, arranged one before the other, by the action of which the surplus metal is removed. Several ties may be operated upon at the same time on one table, and after passing under the cutters they are delivered from the table with rail recesses or seats in a finished state.

The firm makes a specialty of metal ties for light and portable railways, and has supplied them for light railways for agricultural, mining, and construction work in many countries with succesful results. These ties are of steel plates, with one or two vertical corrugations lengthwise of the tie, and having the sides bent down; the ends are open. The corrugations are cut away at the rail seats to let the flange of the rails rest on the flat part of the plate, and a serrated metal key is driven between the rail and the side of the recess thus formed. There are no bolts, clips, or rivets. Ties with two ribs or corrugations are used at rail joints. For portable railways, with rails weighing up to 14 pounds per yard, the ordinary ties are 5 inches wide and the joint ties 6⅝ inches wide; for semi-portable railways, with rails weighing up to 30 pounds per yard, the ties are 5⅛, 5¾, and 6¾ inches wide; for light railways, using locomotives, with rails weighing up to 40 pounds per yard, the ties are 9½ inches wide at the bottom and about 3 inches deep. Ties of this latter form have been used on the Donna Christina Railway in Brazil. Ties for main lines laid with flange rails are of somewhat similar form, but with closed ends; to make a seat for the rail, the metal of the corrugation is pressed down level with the surface of the tie, thus thickening the metal at the seat; a steel key is driven between the rail and the side of the corrugation, and in pressing down the metal it is made to project over the seat so as to form a clip to hold the rail flange. This type of tie was patented in the United States February 2, 1886 (No. 335,523). Another form of tie consists of two pressed steel bowls connected by a wrought-iron tie-bar; each bowl is made of a steel plate flanged down to the form of an oblong box; it is flat on top with outward flaring sides, and rounded ends corrugated vertically. The tie-bar passes through the bowl, and is held by a flat curved cotter lying in a depression in the top of the bowl. There are two transverse corrugations, which are pressed down at the middle to leave room for the rail flange, and the rail is secured by two serrated steel keys. The weight is said to be only about half that of the ordinary cast-iron bowls.

The Wood steel ties.—The steel tie designed by Mr. Charles Wood, of Middlesborough, is said to have been the first steel tie used with flange rails on English railways, and to be still in use in England and the British colonies. It is of modified Vautherin type, of inverted trough section, and having horizontal flanges on the lower edges. (See Plate No. 4.) Each rail fastening consists of a half hoop or crescent of steel, the lower part being inside the tie, and the ends projecting upwards through holes in the top, having stops or lugs to prevent them from rising too high and to bring them into proper position. The outer end of the crescent is bent over to bear on the outer flange of the rail, while the inner edge projects higher and has a wooden key driven between it and the rail, the key bearing against the web and flange of the rail. Some of these ties were tried on the Northeastern Railway in England; and they have also been used in South America. For light and portable railways steel ties with different forms of clips and bolt fastenings are used.

The White tie.—This is a patent pressed-steel tie, designed by Mr. Henry White, of Newport, and manufactured by Ibbotson Bros., of Sheffield. At a meeting of the British Association in 1887, Mr. White read a paper on "An improved steel railway tie with chairs pressed out of the solid," the following notice of which is taken from Engineering, London, England, September 23, 1887:

"This was a trough section tie, to suit any ordinary type of rail, and the chairs being stamped on it there were no bolts or rivets required. Hydraulic presses with suitable dies are used. The steel trough is first cut to the required length, heated, and inserted between the open dies of a press, or, if both chairs are made at once, of a pair of presses. These roughly form two corrugations at each end, corresponding with the jaws of the chairs. The metal for this is gathered up endwise, thus shortening the original length of the piece of steel operated on. Another heat being taken, the partly-made tie is placed between the dies of the finishing press and the jaws are given their final form. The lower dies in this case have two hinged pieces which project upwards, and when the upper dies descend they close inwards, causing one of each pair of jaws to assume the undercut form necessary to fit the rail and hold it firmly in its place. A loose piece, resembling the lower part of the rail, is inserted between the jointed pieces, to form a resistance block for them to close against. It was claimed that ties so formed give a larger base to the rail, hold it more firmly, and are stiffer than any others hitherto used."

The Sampan tie.—The Sampan combined railway tie and chair is a comparatively recent invention, and, I believe, has not yet been tried. It is intended to be made of cast-steel, the recent improvements in steel manufacture enabling a reliable quality of material and work to be obtained at reasonable cost. The tie is of shallow inverted trough section, with outward flaring sides and closed ends; a middle rib runs along the whole length of the under side of the tie, and this rib is deeper than the sides; there are also four transverse ribs, one under each rib and two intermediate. (See plate No. 4.) The thickness is increased at the rail seat. The chairs for bull-headed or double-headed rails are cast with the tie and form a part of it, the rails being secured by wooden or metal keys in the usual way. The joint ties are of extra width at the ends, and the rails are secured in the joint chairs by two cast steel keys, which are drawn and held together by a bolt passing through them parallel with the rail. This is claimed to make an efficient joint, dispensing with splice-bars and bolts. If desired, the ends with the chairs can be cast separately and connected by a tie-bar; this arrangement is said to be adapted for railways in South America and other countries where the traffic is not too severe. These ties have been patented by the Railway Sleeper and Tie Company, of Manchester.

The Bankart tie.—This is a cross tie, the invention of Mr. Hubert Bankart, consisting of an I beam laid on its side (⊢⊣) with a part of the upper flanges cut away to allow the rail to rest on the horizontal web; the inner flange of the rail is overlapped by the flanges of the tie, which are undercut, and on the outer side of the rail is an angle wedge or key, bearing on the rail flange and web, and having a rib at the back which fits into a groove in the flanges of the tie and prevents vertical motion. (See plate No. 4.) No bolts or nuts are required, this fastening being used at the rail joints. The key may be placed on the inside or outside of the track, but the flanges must be cut according to which arrangement is adopted. These ties are said to have been tried in Brazil, but I have not been able to obtain any definite information respecting them.

The Bagnall ties.—The firm of W. G. Bagnall, of Stafford, manufactures different forms of metal ties, principally for light and portable railways, and the ties have been used to some extent. The type used is a pressed steel cross-tie, narrower and deeper at the middle than at the ends, and having grooves and ribs running lengthwise on the surface. For permanent roads a tie is used having a groove running from each end nearly to the middle; corrugated steel clips are riveted on and a steel key is driven between the rail flange and one of these clips. (See plate No. 4.) Another form of tie with riveted clips has the groove running in from each end and two raised ribs along the middle portion of the tie. Joint ties of this form are of extra width, with two grooves at each end and three ribs at the middle. With other forms of ties lugs are stamped up out of the metal to hold the rail flanges, the rails being secured by keys. A tie for collieries, mines, and light tracks has the lugs bent over to embrace both flanges of the rail, the rail being slipped under the lugs, and no keys or other loose pieces being used. For portable railways, the rails and ties are riveted together to form sections of track, one end of the rails of each section having the splice-plates riveted on.

The Tredegar ties.—Besides the steel ties made for the Metropolitan Railway, the Tredegar Iron and Steel Company makes other forms, including corrugated steel ties for use with flange rails. These are made of various sizes, and weigh from 12 pounds (2½ pounds extra for fastenings) for a gauge of 24 inches to 62 pounds (4 pounds extra for fastenings) for standard gauge.

The Nut and Bolt Company's ties.—The Patent Nut and Bolt Company, of Newport, manufactures a tie of double channel or H section. The lower part is of trough section, $2\frac{9}{32}$ inches deep, $10\frac{1}{4}$ inches wide at the bottom, about $5\frac{1}{2}$ inches wide on top, and having on the upper part two vertical ribs forming a channel $1\frac{1}{2}$ inches deep and $4\frac{5}{8}$ inches wide. The horizontal part is eleven-thirty-seconds of an inch thick, and the sides of the channel are three-eighths of an inch thich. For double-headed rails the fastenings consist of two loose jaws. The outer one fits the web of the rail and the under side of the head. It rests on the horizontal part of the tie, and has a hooked lug on the bottom which passes through a hole in the tie and takes a bearing on the inside. On the inner side of the rail is a similar jaw, but with the top flat and having a slot near the base. A flat taper steel key is driven horizontally through slots in the sides of the channel and the base of the jaw in a similar way to the fastening used with the Denham-Olpherts plate-ties in India. The chair and fastening make a heavy and cumbrous arrangement, and the jaws are liable to wear and thus cause rattling. It has been suggested that the outer jaw might be riveted. The holes for the keys and chairs are punched cold. The ties weigh 154 pounds each. They are said to have been in service under heavy traffic at the Alexandria Dock, Newport, and on the lines at the works of the manufacturers.

The Quetch ties.—This system of track has been described in an Indian paper as an English system, and it is said to have been awarded a bronze medal at the Railway Exhibition at Paris, in 1887. The rails are of bridge section with very wide flanges, about 14 inches wide over all. The joint and intermediate chairs consist of channel plates with lugs on the side to hold the rail flanges, and a rib in the middle to fit into the hollow of the rail, keys being driven through the webs of the rail and this rib. The gauge is maintained by transverse tie-rods fastened by vertical cotters. The track seems to resemble the Macdonnell track on the Great Western Railway.

The following is given as the weight per mile of single track:

	No.	Weight.
		Tons.
Rails, 24 feet long, 100 pounds per yard	440	165.00
Chairs:		
Joint, 90 pounds each	440	43.75
Intermediate, 45 pounds each	1,320	
Tie rods, $1\frac{1}{4}$ inch diameter, 30 pounds each	888	12.25
Keys:		
Joint, 3 pounds each	1,760	4.00
Intermediate, 3 pounds each	1,320	
Springs, for keys	3,080	.25
Cotters, for tie-rods, 3 pounds each	1,760	2.50
Total	11,008	227.75

The MacLellan ties.—The MacLellan & Smith patents are for ties of embossed steel, either in the shape of bowls or cross-ties. A description of the former will be found in this report, under "India" (Calcutta Port Railway), and of the latter under "Australia" (South Australian Government Railways). (See plates Nos. 18 and 25.) They are manufactured by P. & W. MacLellan, of the Clutha Iron Works, Glasgow. MacLellan's wrought-iron ties have also been used in India, on the State Railways.

The Chair and Sleeper Company's tie.—The tie manufactured by this company, of Widnes, Lancashire, and in use on the North Staffordshire Railway, is a steel tie of V-section. For double-headed rails, the ordinary cast-iron chairs are secured to the flanges. For flange rails an angle plate at each end, as long as the width of the top of the tie, is secured by two rivets, and supports the outer side of the rail, while two loose riveted clamps are forced round upon the rail flange on the inner side. At joints the vertical part of the riveted angle-bar is as long as a splice-bar, and has four projections or studs, which engage with the holes in the webs of the rails. Bolts are thus dispensed with. The tie is intended for light railways, collieries, etc., as well as for main lines.

SUMMARY OF METAL TRACK FOR ENGLAND.

	Miles.
Northeastern Railway	5
London and Northwestern Railway	56
Midland Railway	5
Great Northern Railway	¾
London and Southwestern, London, Brighton and South Coast, Metropolitan, Metropolitan District and Mersey Railways (estimated)	¾
Great Eastern Railway	2¼
Total	70

SCOTLAND.

GENERAL REMARKS.—The length of railways in Scotland is about 2,900 miles, laid exclusively with wooden ties.

GREAT NORTH OF SCOTLAND RAILWAY.—Mr. P. M. Barnett, chief engineer, writing in August, 1889, stated:

> Metal ties have not been tried on this line. The ties used are of Scotch fir, 9 feet long, 4½ inches thick, 5½ inches face, and 10 inches wide at bottom. All the ties are creosoted, and the cost, including creosoting, was, at the time of the report, 56 cents per tie. The forests from which the ties for this line are supplied are in the counties of Aberdeen, Banff, Elgin, and Inverness.

HIGHLAND RAILWAY.—Mr. M. Patterson, chief engineer, stated in August, 1889:

> Metal ties have never been tried on this line. Scotch fir and larch and some Baltic fir are used. The Scotch and Baltic fir is all creosoted, and the company has now begun to creosote the larch ties. The ties are 9 feet long; the foreign ones are of rectangular section, 10 by 5 inches, and the native ones are slabbed on the back for a breadth of 5 inches to give a seat for the chairs. The larch ties cost 84 cents to 86 cents and the fir ties 60 cents, when creosoted. The line is in the best part of Scotland for native ties, and considerable quantities are sent to lines in the south of Scotland and some to England.

IRELAND.

MIDLAND GREAT WESTERN RAILWAY.—Some years ago Mr. James Price, while chief engineer of the road, introduced a system of cast-iron ties, experimentally, and obtained excellent results. The following description refers to ties of the type used, but as subsequently improved upon by Mr. Price, who has furnished me the particulars. Each tie consists of two boxes and a tie-bar. The boxes are 6 by 6 inches square, 4¾ inches deep, open at the top; they are cast with a hollow base 12 by 12 inches square, 2 inches deep, and one side of the box (transverse to the rail) is extended to the width of the base, having a bolt hole in each wing. The box is partly filled with a special mixture of "sawdust asphalt," consisting of sawdust mixed with well-boiled tar, as little of the latter as possible being used. This material is said to be everlasting, permanently elastic, and very cheap. Upon this is placed a plate fitting into the box like a piston, and the rails (of flange section) rest on this plate and not on the sides of the box; so that they have a firm but elastic bearing. The tie-bar is 3 inches deep by half an inch thick, with a clip or jaw on the upper edge at each end, to hold the outer flange of each rail. The inner flange is held by a short flat plate of the same shape as the end of the tie-bar. Bolts of 1-inch diameter pass through the plate, tie-bar, and the wings of the box, and by the use of bolts with tapered necks a very strong grip can be given on the rail flange. The ballast is brought up level with the top of the boxes.

FRANCE.

General Remarks.—In this country no railway has definitely adopted metal ties for general use, but experiments with different forms of ties have been made and are still being conducted on five of the seven principal railway systems; in some cases to a sufficient extent to enable conclusions to be drawn as to comparisons between track on metal ties and on wooden ties. There has been a tendency toward the designing of ties of complicated construction, made up of a number of parts or difficult to manufacture; such ties, however, are necessarily more expensive and troublesome than ties which are simple in design and easy to manufacture, and for these reasons their wider introduction is not probable, after practical trials shall have proved their deficiencies. The majority of metal ties now in use are of forms derived from the type designed by Mr. Vautherin, a French engineer; this type consisted of a cross-tie of inverted trough section, with sides flaring outward from the top, and having a narrow horizontal flange on each lower edge. The Vautherin tie is the basis of the form of a very large number of the ties designed and introduced within recent years. These ties were first used in 1864, on the Paris, Lyons and Mediterranean Railway, and were used later on the same company's lines in Algeria. Mr. Clerc, of the Western Railway, in a paper published in the Revue Générale des Chemins de Fer, Paris, March, 1889, stated that of the numerous systems of metal ties which have been tried, the majority had not proved satisfactory, and only a few would bear close investigation. Of these numerous systems few had been designed by persons experienced with railway work; for while the manufacturers have considerable interest in the adoption of metal ties, most railway engineers prefer wooden ties, and difficulty in obtaining wood appears to them to be the only reason justifying the use of metal ties. The time when this difficulty will really necessitate the use of metal ties can not yet, he says, be foreseen. The price of wooden ties was then less than it had been during thirty years, and this reduction was apparently due to the development of certain districts and the facilities of transportation resulting from the extension of the railway systems. The use of creosoted ties has increased the durability of the track, and no limit of service can yet be assigned to ties of creosoted beech; such ties have been in service for twenty-five years, and were in good condition at the end of that time, except a few not thoroughly treated and some which had been split, cut by the chairs, or otherwise damaged, but which had not decayed. Nevertheless, Mr. Clerc believes that the question of the use of metal ties should not be overlooked, and trials have in fact been made upon the line with which he is connected.

In 1885 Mr. Bricka, engineer in chief of the state railways, was directed by the minister of public works to investigate the principal systems of metal track in use in Europe, and he presented a very complete and valuable report, embodying the results of his investigations. He came to the conclusion that the use of track with metal ties is advantageous, and is not in general more expensive than that with wooden ties, when the proportion of the prices does not exceed 8 to 5. He recommended cross-ties of the Berg-and-Mark or Post sections, both of which are modifications of the Vautherin tie. He further recommended that a series of practical trials should be carefully conducted. If properly carried out the cost would not be great, and the results thus obtained and recorded would be extremely valuable. He did not think, however, that the use of metal ties would become general in France to replace wooden ties, as there are yet extensive timber resources and the use of wood will be always economical in forest districts. A point not referred to, however, is the superiority of track on metal ties over that on wooden ties, especially under heavy and rapid traffic. Metal longitudinals have only been tried to a very limited extent.

Use of old rails.—Several forms of ties in which old rails are to be used have been designed by Mr. Ozanne. They consist of different forms of cast-iron plates and rail chairs combined, placed in pairs and connected by an old rail, forming a tie-bar, bolted or keyed to them.

STATE RAILWAYS.—The following information is taken from a special detailed report, sent to me in March, 1888, by Mr. Bricka, the engineer in chief, and from other reports sent by division engineers, dealing with the several queries contained in the circulars accompanying my letters of inquiry.

The reason for using metal ties was that engineers had learned from the experiments and trials made in Germany, Austria, and Switzerland that the use of metal ties offered considerable advantages; the engineers, therefore, decided to employ such ties to a sufficient extent to enable them to judge for themselves as to the results to be obtained from their use. Up to the date of Mr. Bricka's communication (March, 1888) the track had remained in good condition; it was as firm as and more solid than track on wooden ties; there was no trouble with the rail attachments, and no breakages had occurred; no difficulty was experienced with the maintenance, which, after a time, tended to become less than the maintenance of track on wooden ties. The rails are of double-headed section on some parts of the line, and of flange section on other parts. The ordinary cast-iron chairs have been used on some of the metal ties on account of the large stock on hand of double-headed rails; but with metal ties there is less need of such chairs for the purpose of distributing the pressure. The joints are suspended and are spliced by fish-plates and four bolts. The ballast is of sand, gravel, or broken stone; on the outside of the track it is brought up level with the under side of the rail head; on the inner side it is level with the bottom of the rail and is crowned toward the middle of the track. The wooden ties are of pine from the Landes, impregnated with chloride of zinc, which cost 52 cents each in the southwest district of the system. Oak ties cost 95 cents, and, since 1886 or 1887, these ties also have been impregnated with chloride of zinc, which increases the price 11 cents per tie. The temperate climate of the region in which this system of railways lies is favorable to the life of wooden ties. Atmospheric agencies do not appear to affect the metal ties, which only corrode in tunnels and when laid in ballast containing sulphurous material. No preservative process or coating is applied to these ties. The engines with three axles weigh 56 tons, and those with four axles 75 tons, including the tender. The load on the axles of the engines is from 10 to 13 tons. The speed of express trains ranges from 38 to 50 miles per hour. The lines are of standard gauge, 4 feet 8½ inches.

(*A*) *Paulet and Lavalette ties* (See plate No. 5).—These ties were laid in August, 1885, for a length of 11,119.20 feet, on the line from Paris to Bordeaux (section from Montreuil-Bellay to Niort). Mr. Tyndall, of Tours, was the engineer in charge. There are nine trains per day, with a speed of 37 to 50 miles per hour. The line is double track, and the profile and alignment of the track laid with these ties are as follows:

	Feet.
Profile:	
Level	2,246.80
On grades of 1 per cent	5,412
On grades of .5 per cent	721.60
On grades of .1 per cent	2,738.80
Alignment:	
On tangents	3,690.69
On curves of 1,640 feet radius	7,428.51

The ties are made of iron and are of two forms, single and double. The single ties are made of two angle-irons 3.6 inches wide, 2.8 inches high, .36 inch thick, and 7.55 feet long; these are placed back to back and have the ends bent slightly outward. A rib on the bottom of each of the two rail chairs rests between the angle-irons, and each chair is secured by four rivets passing through the angle-irons and rib. The weight is about 165 pounds per tie. The double ties are placed 24 or 32 inches apart, and are connected at the ends by irons of the same section bent to the form of a **U**, the legs being parallel with the main angle-irons and riveted to them; the ribs of the chairs lie between the main and end pieces and are secured by the rivets. The double ties used at curves have the angle-irons about 32 inches apart, and weigh 308 pounds each; those used at the rail joints have the angle-irons about 24 inches apart, and weigh 290.4 pounds each. The single ties on straight lines are spaced 33 inches apart, centre to centre, and 32 inches from the joint ties. On curves two of the double ties are substituted for four single intermediate ties, leaving one single tie at the middle. The double ties are spaced 32 inches apart, or 34 inches from the single ties. The ties were manufactured by the Société Anonyme des Hauts Fourneaux, of Maubenge. The first cost was about $45 per ton, and the expense of maintenance is said to be lower than that of track with wooden ties. These ties must be manufactured with great care, as otherwise the rivets may not fit exactly and may throw the track out of gauge. They are more expensive in first cost and are less advantageous than ties of the Vautherin type. The rails used are of double-headed section, 5.3 inches high, with heads 2.4 inches wide, and weighing 76.5 pounds per yard. The upper parts of the chairs are of the usual form, and the rails are secured in them by keys. The ballast is of broken granite, and is about 22 inches deep between the rails and 12 inches deep under the ties. The width of ballast is 23.4 feet on top, extending 3.4 beyond the ties. The road-bed at subgrade is flat.

Mr. Bricka stated in his letter that the Paulet and Lavalette ties were only used on a short length of track. They have given satisfactory results, but on account of the high price and the chances for damage which they present, the ties derived from the Vautherin type are much preferred, more especially as their advantages have already been demonstrated in other countries. Mr. Tyndall, division engineer, writing in May, 1888, in regard to these Paulet and Lavalette ties, stated that those laid up to that date, for a length of 2.5 miles, had given satisfaction, no chairs having been broken and no rivets loosened. He thought that they would be better if made 8.2 feet long instead of 7.55 feet, and that for sand ballast ⊥ irons should be used, with the inner flanges just wide enough to meet, so as not to allow the sand to pass up into the tie while being tamped. The track was good, and the cost of keeping it in repair was about the same as for the track alongside of it, which was laid on wooden ties.

(*B*) *Vautherin ties of uniform section for double-headed rails* (See plate No. 5).—At the time of the report there were on the line from Paris to Bordeaux 4.25 miles laid with these ties on the section between Chartres and Bron, 3.1 miles were being laid on the section between Niort and La Rochelle, and ties were being manufactured for 18.6 miles more. Those on the first section were laid in January, 1887, under the supervision of Mr. E. Colin (See paragraph D). On this section the ties are on the level for about 1 mile, and for the remainder of the distance on grades of from 1.2 per cent. to .2 per cent.; about 2.67 miles are on tangents, and the remainder on curves of from 1,804 feet to 9,840 feet radius. The line is single track, and the traffic consists of twenty-two trains per day, the speed of the express trains being from 37 to 50 miles per hour. Mr. Delaunay was the engineer in charge of the second section, the traffic of which consisted of twelve trains per day. The rails are of similar section and weight to those already described. The ballast is of sand and clean gravel, about 13.2 inches deep under the ties. The width of the ballast bed is about 11.7 feet on top and 17 feet at the bottom. The road-bed at subgrade is crowned. The ties are of modified Vautherin type, of uniform section throughout, having the top table of uniform thickness, and having ribs instead of horizontal flanges on the lower edges. They are 8.2 feet long, 4.8 inches wide on top, 3.2 inches deep, and 10.12 inches wide at the bottom; the thickness of the top table is .4 inch, while that of the sides varies from .28 inch near the bottom to .32 inch near the top. The weight is 126.72 pounds. In the track they are spaced 21 inches apart, center to center, at joints, and intermediate ties, 39.2 inches apart. No special arrangement of the ties is used at curves. The ties are of mild steel and are manufactured by the Société de Denain et d'Anzin, and cost about $30 per ton delivered at the track. The expense for maintenance during the first year is about the same as with wooden ties, but it diminishes afterwards. This type of tie has given general satisfaction, and judging from experience in other countries, they should have a life of at least thirty years. The chairs used are of cast-iron, of the ordinary form, but having a lug on the under side which fits into a slot in the tie; they are fastened by two bolts with ⊥ heads inside the tie.

(*C*) *Vautherin ties of varying section, for flange rails* (See plate No. 6).—On the line from Paris to Bordeaux (section between Chartres and Bron) 4.2 miles were laid in January, 1887, under the supervision of Mr. Colin (See paragraph E). About 1 mile of this distance is on the level, the remainder being on grades of .7 to .1 per cent.;

about 3.25 miles are on tangents, the remainder on curves of 5,000 to 8,200 feet radius. The traffic consists of twenty-two trains per day. The ballast is of broken granite and the section of road-bed is as described in Paragraph B. The rails are of flange section, 5.2 inches high, 5.2 inches wide over the flange, with a head 2.4 inches wide, and weigh 78 pounds per yard. On the line from Tours to Sables (section between Bressuire and Sables), 4.6 miles were laid in March, 1887, under the supervision of Mr. Madelaine. About 1.25 miles are on the level, the remainder being on grades of 1.4 to .7 per cent.; about 2.1 miles are on tangents, and the remainder on curves of 2,427 feet to 6,000 feet radius. The traffic consists of twelve trains per day. The ballast is of the same material and the road-bed is of the same general section as described above, except that the bed at subgrade is flat and not crowned. The rails are of flange section, 5.2 inches high, 4 inches wide over the flange, with a head 2.4 inches wide, and weigh 76.4 pounds per yard. The ties are of the modified Vautherin type, of varying section and thickness of top table, being somewhat similar to the "Post" type of tie (Netherlands State Railways). They are very similar to those described in Paragraph B, but the thickness of the top table varies from .40 inch or .44 inch at the rail seat to .28 inch or .32 inch at the middle; they are 8.52 feet long, with a top table 6 inches wide. They are bent to give the rails an inward cant of 1 in 20, and the ends are closed. They are of mild steel and weigh 124.3 pounds each. They were manufactured by the Société de Denain et d'Anzin, and cost $34 per ton. The expense for maintenance during the first year is about the same as with wooden ties, but it then begins to diminish. The ties have given good results and are expected to last thirty years in service. The fastenings used are of two types; the first consists of a bolt on each side of the rail flange, the bolt having a ⊥ head inside the tie, and a clamp or washer held down on the rail flange by the nut; the clamp has a projection which fits into a slot in the tie; the second type of fastening consists of an arrangement of gibs and cotters, each side of the rail flange being held by a gib, and a vertical cotter being driven on one side. This latter type is said to be satisfactory, and to appear to be superior to the fastening by bolts and clamps, a result which is at variance with early experience with gib and cotter fastenings, it having been found, as a rule, that the cotter worked loose, or else rusted in so that it could not be moved and must be broken off, the whole fastening, as a rule, soon becoming loose enough to make a noisy rattling track. Some of the German railways, and the Western Railway of Switzerland, also report good results from the use of an improved gib and cotter fastening. For rail lengths of 20 feet the end ties are spaced 24 inches, center to center, and the intermediate ties 36 inches; for lengths of 36 feet, the middle and end ties are spaced 24 inches, center to center, and the intermediate ties 39.2 inches.

Mr. Edmond Colin, engineer of the First Division (Premier Arrondissement), sent me in July, 1888, a detailed report of experiments made under his charge on this division, with three types of metal ties. The trials were made on the line from Paris to Bordeaux (section between Chartres and Bron), on a single track. These ties had, however, been in service too short a time to enable their durability to be determined, but no breakages had been observed since the ties were laid. They were all of mild steel, and were manufactured by the Société de Denain et d'Anzin. They were spaced 24 inches apart, center to center at the joints, and 39.2 inches intermediate. The ballast used is very fine sand or gravel, mixed with 40 per cent. of broken flint; it is brought up level with the top of the ties, and is about 14 inches deep under the rail seats, where it is packed into the tie. The ballasting has to be done with great care, and requires at first more continuous care with metal ties; but it holds in them better, and after the first year the maintenance requires considerably less time. The track on metal ties keeps in better line and surface and is more solid than track on wooden ties. The oak ties used cost 92.2 cents each, and 5.6 cents more if treated with chloride of zinc; their average life is twelve years. The climate of the region is temperate, but the wooden ties are affected by the various conditions of the ballast, according to the seasons; while moist in the spring and autumn, it dries completely in the summer; the fastenings then work loose and the tie has a tendency to split. With the metal ties the atmospheric influences give no cause for apprehension, and it has been observed that these ties do not rust more than the rails. The traffic consists of fourteen passenger trains (the speed of express trains being 37 to 50 miles an hour) and eight freight-trains (carrying merchandise, grain, wine, and cattle) in twenty-four hours. The locomotives are of three classes: (1) with two axles coupled, weighing 36 tons; (2) with three axles coupled, weighing 33 to 37 tons; (3) with four axles coupled, weighing 53.3 tons; the load per axle is from 11 to 14 tons. Following are the details of Mr. Colin's report:

(*D*) *Modified form of Vautherin type of tie, with uniform section and thickness throughout* (See paragraph B).—These ties were laid between November, 1886, and February, 1887, for a length of 4.4 miles; 1.25 miles was on the level and the remainder on grades of .13 to 1.15 per cent.; about 3 miles were on tangents, and the remainder on curves of 1,640 to 9,840 feet radius. The section is uniform for the whole length, and is that of a Vautherin tie of which the upper table is widened, and the sides have a rib along the bottom edge instead of a horizontal flange. The tie is horizontal, quite flat, 8.2 feet long, 4.8 inches wide on top, 9.2 inches wide inside at the bottom, and 3.2 inches deep; the sides flare outward from the top and then turn down vertically; the thickness varies from .28 inch and .32 inch at the sides to .40 inch on top. The weight is 129 pounds. The ends are bent down vertically to close the ends of the trough. A few of the ties were coated with coal tar at the works; the others were not given any preparation. The cost was $30 per ton at the market rates of 1886 and $28 per ton at those of 1888. The maintenance expense during the first year was nearly equal to that of track with wooden ties, but it tended to diminish sensibly after the first year. No special arrangements are made on curves. The rails are of double-headed section, 36.08 feet long, weighing 76.5 pounds per yard. They are carried in cast-iron chairs, which are similar to those used on wooden ties, but have a lug on the under side which fits into a slot in the top table of the tie. Each chair is fastened by two T-headed bolts, and the rails are secured in the chairs by wooden keys. The rails are laid to break joint, the joints are suspended, and are spliced by fish-plates and four bolts. The results obtained have been satisfactory, the track keeping in good line and surface. The passage of trains is as smooth as on a track laid with wooden ties; at first it was a little harder, but there is now no difference. The maintenance presents no difficulty, and there is only one special precaution to be taken for lining of the track. To shift the track in lining up it is necessary, owing to the closing of the ends of the tie, to open up the ballast to the outside of the end of the tie on the side towards which it is to be brought back, and to open up the ballast in the interior of the tie from the opposite end; unless this is done the track will shift back to its original position on the passage of the first train. The rail fastenings give no trouble. During the first few months there were some chairs broken, which was attributed to insufficient packing of the ties. Only one tie had been found broken; it was broken transversely under the chair, and the break appeared to be due to a defect in the manufacture. The replacing of this tie was done without any difficulty by removing the ballast, sliding the new tie in under the rails, and then attaching the chairs. The ties behave well, and the only improvement suggested was the strengthening of the rail chairs. The opinion given was that this type of tie is quite satisfactory and gives perfect safety.

(*E*) *Modified form of Vautherin type of tie, with varying section* (See paragraph C).—These ties were laid in February and March, 1887, for a length of 4.46 miles; 1.24 miles were on the level, and the remainder on grades of .12 to .7 per cent.; 3.53 miles were on tangents, and the remainder on curves of 4,920 feet to 8,200 feet radius. The general form is similar to that described above (paragraph D), but the section varies at different parts of the length, and the top table has an extra thickness of metal at the rail seats. The tie is bent to give the rails an inward inclination of 1 in 20, and the ends are closed. The length is 8.52 feet; width of top table, 6 inches; weight, 124.3 pounds. Some are tarred at the works, the others are used without treatment. The price was $34 per ton at the market rates of 1886. The experience as to cost of maintenance has been the same as noted for the preceding type (paragraph D). No special arrangements are made on curves. The rails are of flange section, 36.08 feet long, weighing 76.5 pounds per yard. They are placed directly on the ties. Some are fastened to the ties by gib and cotter fastening, a vertical cotter being used; the others are fastened by bolted clamps. There are two clamps to each rail; they are of ┌ shape; the horizontal part bears on the flange of the rail and the vertical part rests on the tie and has a projection which fits into a hole in the top table of the tie; a tee-headed bolt passes up through the tie and clamp and is secured by a nut on top. The track was first laid with even joints, but was then being changed to break-joint, that system being preferred; the joints are suspended and are spliced by fish-plates and four bolts. The remarks as to results and maintenance are the same as for the preceding type described (paragraph D), except that the passage of trains was still a little less smooth than on track with wooden ties. The rail attachments gave no trouble and there had been no breakage. Experience up to that date had shown that the gib and cotter fastenings were better than those with clamps. The opinion given was that this type made a very solid track and one very easy for maintenance.

(*F*) *Boyenval and Ponsard tie* (See plate No. 6).—Ties of this type were laid in April, 1888, for a length of 298.48 feet on a tangent of a grade of 0.25 per cent. They are of uniform section throughout, and the cross-section is that of three troughs, the middle one open at the top and the two outer ones open at the bottom. The ties are horizontal, 8.2 feet long, 8 inches wide on top, 10.2 inches wide at the bottom, and 2.8 inches deep; the width of the top is made up of two bearing surfaces 2.4 inches wide and a channel 3.2 inches wide; the bottom width is made up of two channels 3 inches wide, a middle bearing 2.8 inches wide, and two flanges .7 inch wide. The thickness of top and bottom is .32 inch, and of the sides .20 inch. The weight is 129.8 pounds. They were all tarred at the works, and the price was $2.48 each. The ends of the two outer channels are closed by riveted angle-pieces. The rails are of double-headed section, 36.08 feet long, weighing 76.5 pounds per yard; they are carried in cast-iron chairs a little stronger than those used with wooden ties, and having a lug on the bottom which fits into a hole in the tie. Each chair is fastened to the tie by four bolts. No special arrangement would be used for curves. The rails are laid to break-joint; the joints are suspended and are spliced by fish-plates and four bolts. The results obtained had so far been satisfactory, and the passage of trains was as smooth as on a track with wooden ties. There had been no breakages, no trouble with the fastenings, and no difficulty with maintenance, while the lining up was easily effected; the maintenance would not differ much from that with other metal ties. The experience with this type of tie had been too short to allow of any definite opinion being given. It may be noted, however, that the shape is difficult to roll, and the tie can not be considered as easy to manufacture.

The double-headed rails used with metal ties are of "hour-glass" section; 5.4 inches high, with heads 2.64 inches wide and web .72 inch thick at the middle; the radius of the top table is 3.6 inches for a width of 1.6 inches; the radius of the top corners is .38 inch, followed by an inward curve of .88 inch radius. The flange rails are 5.2 inches high, 5.2 inches wide over the flange, and 2.4 inches wide in the head; the head has a top radius of 8 inches, top corners of .32 inch radius, vertical sides, and .24 inch bottom radius. The clamps for flange rails are 2.56 by 2.24 inches over all for the outer flange, and 2.56 by 1.86 inches for the inner flange; the thickness is .52 inch, and the total depth 1.24 inches. The bolt holes are .84 inch square; the nut washers are 1.28 inches diameter, with a hole .84 inch in diameter, and a thickness of .10 inch. The gib and cotter fastening consists of one gib on the outer side, and on the inner side two gibs with a vertical cotter between them; the cotter is 6 inches long, .8 inch thick, 1.08 inches wide at the top, and .76 inch wide at the bottom. The outer holes in the tie are 1.56 inch long, and the inner ones 2.5 inches long; they are 4.56 inches apart in the clear, and .88 inch wide. The chairs on the Vautherin ties have a base of 13 by 4.48 inches, the longer dimensions being length-wise of the ties; the jaws are 4.84 inches wide; the bolts are .76 inch diameter. The chairs for the Boyenval and Ponsard ties have a base of 8 by 11 inches.

Mr. A. Delaunay, engineer of the Saintes division (Arrondissement de Saintes), stated in June, 1888, in regard to the metal ties used on the section from Niort to La Rochelle (See paragraph B), that the trials were made on a length of 3.1 miles; the line was on a tangent and one curve of 3,280 feet radius, and had grades not exceeding .5 per cent. (5 millimeters per meter). The track consisted of steel rails of double-headed symmetrical section, 18.04 feet long, carried on six cross-ties and resting in chairs weighing 21 pounds each. The ballast, which was then being renewed, is of calcareous gravel, very clean and of coarse size, and exceptionally of broken stone screened. For the trials, Vautherin ties of uniform section were employed, weighing 130.24 pounds each, and laid six to a rail length. Special chairs are used, weighing 22.33 pounds, and having a lug on the bottom which fits into a hole in the tie. The bolts attaching the chairs to the ties do not work loose after the first tightening has been made. In laying the ties the rails and joints were not disturbed. For the six months they had been in service the ties had given good results in gravel and broken stone ballast, and made a very stable track, the riding on which was as easy as over a track laid with wooden ties. The packing had to be renewed rather frequently at first. This maintenance work caused an extra expense for labor of about two men per month, who have been added to the gang of five men, whose section of 4.96 miles includes five renewals of metal ties. The first ballasting holds better in sand or gravel than in broken stone. While the trial was too recent to enable him to pronounce on the results obtained, he considered it probable that six months later they would be able without difficulty to reduce the section gang to four men. The traffic consisted of five passenger trains in each direction per day, composed of 50 to 70 cars, and hauled by engines with four coupled axles, weighing 53 tons.

Writing again in December, 1888, Mr. Delaunay stated that his opinion, in common with that of most engineers in France, was that the double-headed or bull-headed rail was the only form suitable with wooden ties for lines with heavy and fast traffic; but he believed, nevertheless, that the flange rail on steel ties would possess all the superiority and advantages claimed by its advocates over those of the double-headed rails. The latter have, however, been used on metal ties on the State Railways only because there was a large stock of these rails which it was necessary to use. Trials with flange rails on metal ties have been made on other divisions with excellent results. He considered that the cause of the metal tie had definitely gained its success, and that its advantages could only be contested by companies whose financial conditions do not permit them to pay at once the existing difference of cost between wooden and metal ties.

The following information was presented by Mr. Kowalski at the International Railway Congress held at Milan, Italy, in 1887:

> Metal cross-ties were used in regular service for about 16.43 miles; there were 2.48 miles laid with ties of the Paulet type, 4.65 miles with a modification of the Vautherin type of tie, using cast-iron chairs, and 9.30 miles with the "Post" tie. The first weighed about 220 pounds each, and the others about 125.4 pounds. They were all of mild steel, but it was intended to try 5,000 cross-ties of hard steel. As the laying of these ties had only been commenced in December, 1886, no precise information as to the results could then be given.

In August, 1889, the engineer-in-chief stated that since March, 1888, metal ties had been laid for a length of about 13.18 miles, 11.68 miles on the line from Tours to Sables d'Olonne, between St. Mesury and Bressuire, and 1.50 miles near the station at Chartres. There had also been 70,000 ties ordered. The total length of the lines of this system was then 1,609.5 miles, and the length actually laid with metal ties about 31.62 miles.

PARIS, LYONS AND MEDITERRANEAN RAILWAY.—Iron ties were laid on this line during 1862 and following years, but by 1872 they had all been taken out. The engineer stated in February, 1888, that these ties were more expensive than wooden ties, and were taken out because, on account of the constant traffic, they made a less firm track and lasted a shorter time. The ties were 7.34 feet long, 5.6 inches wide on top, 8.4 inches wide on the bottom, and 2.4 inches deep; the thickness was .20 inch to .28 inch on the sides, and .32 inch on top, with a middle portion .52 inch thick for a width of 1.44 inches, this being given by extra metal on the under side of the top table. A gib and cotter fastening was used, and not being well adapted for this purpose was very likely the cause of the track being less firm than on wooden ties. On the Algerian lines owned by this company, however, 100,000 ties were laid in 1870 and gave good results; in February, 1888, 60,000 more iron ties were being laid. The conditions on these lines, however, are not the same as those obtaining in France; the burning climate causes the very rapid destruction of wooden ties, while the metal ties, much less injured by the passage of a very few trains, act sufficiently well in service, and enable a certain economy to be realized over the wooden ties on account of their longer life. (See "Algeria").

Vautherin ties were first used in 1864, on the line from Besançon to Lons-le-Saulnier, then in course of construction; 600 ties were used, which were manufactured by the Fraisans Works of the Iron Works Society of Franche Comté.

The present ordinary track is laid with rails 32.8 feet long, placed on twelve wooden ties in main track, or eleven ties at stations, and on branches where the speed is only about 31 miles per hour. In main track they are spaced 24 inches, center to center, at the joints, 28 and 34 inches next to the joints, and 36 inches intermediate; for branches they are spaced 24 inches at joints, 30 inches next to the joints, and 3 feet 3⅜ inches intermediate; for sections with very heavy traffic 13 ties are used, spaced 32 inches center to center. Iron tie-plates, fastened by screws which hold the rails, are used on the ties next to the joint, and the outer angle-bar of each joint has a flange sufficiently wide to allow of the screw passing through it. To prevent creeping, some of the iron tie-plates have one side bent up to fit the rail-flange and web; these plates are screwed to the tie and bolted to the web of the rail.

EASTERN RAILWAY.—In February, 1888, the director of construction reported that up to that time they had made only very limited trials with ties of several forms, and had not been able to draw favorable conclusions for the adoption of any one of these forms in preference to ties of hard wood (oak or beech), simply injected with dead oil of coal-tar (creosote). These wooden ties thus prepared gave results which did not admit of doubt as to their superiority in first cost, in maintenance expenses, and in renewals. The trials with metal ties were, however, being continued, more with a view to the requirements of a probably distant future than to any present interest. The company estimates that the life of its creosoted oak ties is about twenty-five years, and that, therefore, the present introduction of metal ties is not necessary. The road is of standard gauge.

One of the most interesting forms of metal ties tried on this road is a tie designed by Mr. Guillaume, the engineer of permanent way, which has been laid for a length of about 13 miles (See plate No. 7). It is of trough or channel section placed in normal position, that is, with the open part upwards. It is 8.46 feet long, 10 inches wide and 3.2 inches deep; the thickness at the bottom is 0.36 inch. The ends are bent down 3.28 inches below the level of the bottom, in order to offer resistance to lateral motion of the tie in the ballast. The weight of the tie is 171.6 pounds, or about 190 pounds including the fastenings. Each rail rests on two blocks of elm, creosoted and compressed; these blocks are 8.8 inches long, 3.12 inches square under the rail, and have the top inclined to give the rail an inward inclination of 1 in 20; they are thick enough to carry the rail clear of the sides of the tie. The elm blocks are made in England, and give much better results than blocks of oak, not compressed, which have also been tried; they have not allowed any slack or play, and have not been seriously depressed or cut under the flange of the rail. The absence of metal contact between the rail and the the sides of the tie is claimed as an advantage; this might be true with such a form of tie, which would give only two narrow bearing surfaces, but it has been conclusively shown with other forms of ties that the metal contact, where there is a wide bearing surface, need not be objectionable if proper fastenings are used. The rail is fastened by two flat steel plates, cast and annealed, placed between the wooden blocks and sides of the channel; each plate has a hooked lug on the upper part of one end to hold the rail flange, and has also a stud on the side fitting into a hole in the side of the channel; the plates weigh about 4.07 pounds each, or 16.28 pounds for the set. They can be placed or removed separately, after driving out the wooden blocks, without disturbing the rails, thus rendering renewals easy; it would seem, however, as though the fixing of the plates and the driving of the wooden blocks back in place in case of renewals or repairs, would disturb the track and make a good deal of work necessary to adjust it to proper line and surface and give it proper stability in the ballast. The depth from the head of the rail to the bottom of the tie is 8.76 inches. Mr. Bricka reported adversely to this form of tie, on account of the cutting away of the flanges or sides of the channel at the rail-seats, and he was of opinion that experience had shown that wooden bearing blocks were neither necessary nor desirable with metal ties. There are sixteen ties to a rail length of 39.36 feet, spaced 24 inches center to center at joints and 30 inches intermediate, with the fourth and fifth ties from the end of each rail spaced 31.2 inches center to center. The ballast between the rails is level with the middle of the web of the rail, and on the outer side of the track it is level with the middle of the head of the rail. The engineer stated in April, 1888, that the provisional trials were satisfactory, but that they were restricted to making them on a very limited scale, the superiority of properly creosoted wooden ties over all forms of metal ties being established in the minds of engineers. The rails are of flange section, weighing 74.4 pounds per yard; they are 39.36 feet long, laid to break joint. The joints are suspended and are spliced by a pair of fish-plates with four bolts; the inner plates are of deep section, having a vertical web projecting below the flange.

In 1886 one hundred ties of the Post type had been laid.

The following particulars were presented by Mr. Kowalski at the International Railway Congress, held at Milan, Italy, in 1887:

> There were placed, about 1865, 2,200 iron cross-ties, 100 being of the Vautherin type and the rest of a type designed by the company's engineers as a modification. About 1886 there were laid 100 ties of the Post type and 100 ties of a type designed by the engineer. The Vautherin ties weighed 88 pounds, the company's old and new types 109 pounds and 141.15 pounds, respectively, and the Post ties 169.61 pounds. The two latter types were each laid with 50 ties on a tangent and 50 ties on a curve of 3,608 feet radius, with a grade of 0.3 per cent. in the direction of the traffic. The traffic in 1886 consisted of 21,682 trains, of which 12,031 were passenger trains, and 9,651 were freight trains; the average speed of passenger trains is 40.3 miles per hour. The heaviest locomotives, with four axles, weighed 56 tons. The tonnage hauled in 1886 amounted to 4,616,000 tons. The rails were of steel, weighing 60.36 pounds per yard. The ballast was of a sandy nature, fairly good. The Vautherin ties were taken out in about six years; most of them were cracked. The company's old type of ties lasted better, but the work of ballasting was 45 per cent. greater than with wooden ties, and they were all taken out on account of the wear of the fastenings. The other types appeared to give better results, but the experience was then too short to enable any opinions to be expressed. The passage of trains over these ties was very smooth, and similar to that over wooden ties.

Western Railway.—The metal ties, of which I received particulars in March, 1888, were invented and manufactured by Mr. Chappee, at Mans, and were laid, in May, 1887, for a length of about 656 feet on the line from Paris to Havre, under the supervision of Mr. Banchal. They are on curves of 4,920 feet radius and a grade of 0.5 per cent. The tie consists of a wrought-iron inverted channel iron, upon which the rail-chairs are cast in place. (See plate No. 7.) The channel iron is 8.2 feet long, 8 inches wide, and 2.8 inches deep; the thickness of the top table is 0.36 inch. The upper part of the cast-iron chairs is of the usual form for a double-headed rail, but there is a wing of ┐-shape on each side, which fits over the side of the tie. These wings are 4 inches wide, 4 inches thick at the side of the tie, and 3.6 inches deep below the top of the tie. They thus embrace the flanges of the channel and project 2 inches inside and outside of them; while at the middle, under the rail, they completely fill the space inside the channel. The width of the lower part of the chairs, over the wings, is 12 inches, and the rails have a bearing for that distance, which is double the bearing given by an ordinary chair. In each side of the tie are two holes 0.8 inch diameter, one to each chair, through which the metal can flow and so securely fasten the chair in its place. Both chairs are cast at the same time. The weight, including chairs, is about 297 pounds. The cost is about $3 per tie, the channel-iron itself costing $2. The time of the trial—one year—was then too short to permit of the maintenance expenses or the probable life being determined. The ties are not painted or otherwise protected against rust, and no special arrangements are made for curves. The rails are of steel, of double-headed section, and weigh 78 pounds per yard. They are secured in the chairs by wooden keys. The joints are suspended and are spliced by a pair of fish-plates and four 1-inch bolts. One of each pair of plates has a vertical web projecting below the rail. The ballast is of quarry chips, about 12 inches deep under the ties. The road-bed at subgrade is horizontal. The ties are spaced as follows: For a rail 19.668 feet long, 24 inches, center to center, at joints, 28 inches next to the joints, and 32 inches intermediate; for a rail 26.24 feet long, 24 inches at joints, 29.08 inches next to the joints, and 34 inches intermediate, except the middle ties, 34.04 inches. The climate is temperate, its hygrometric condition average, and it exercises no particularly destructive influence on the ties. In March, 1888, the director of works stated that there are found in France, in quantity more than sufficient to meet the demand, excellent species of wood for ties, which are delivered in the form of ties at advantageous prices and which would always be given the preference over metal ties. Under these conditions, and without being indifferent to the investigations which have been made in various places in regard to the substitution of metal for wood for service as ties, this company had only made very limited trials of metal ties. In sending particulars of the tie above described, it was stated that the experiments were too recent to enable any reliable conclusions to be drawn as to the advantages or disadvantages, or any opinions to be formed based on the experience acquired. These trials are not of any immediate interest to the company, as the railway is largely, and under advantageous conditions, supplied with ties of oak or beech of good quality, which when creosoted cost about $1 each and last about twenty-five years.

In a short article in the Revue Générale des Chemins de Fer, March, 1889, Mr. Clerc, the director of works, stated that after having made trials, lasting during two years, of the metal ties already described, on parts of the line under the heaviest traffic, the company had ordered 5,000 more of the same type, with some modifications suggested by experience, in order to carry on the experiments on a large scale. This additional step is interesting, when the statements made by Mr. Clerc in March, 1888, are considered, as the metal ties seem to have been looked upon with favor in spite of the plentiful supply of wood. (Mr. Chappee also proposes to make the tie with the channel-iron placed with its open side upward.)

The company exhibited specimens of its track at the Paris Exposition of 1889, and the following tables of weights are taken from Engineering, August 9, 1889.

Table of metal track. (*Weight per yard*=527 *pounds*).

Material for 39 feet 4 inches of track.	Unit weights.	Separate weights.		
		Steel.	Cast-iron.	Wrought iron.
	Pounds.	*Pounds.*	*Pounds.*	*Pounds.*
2 rails, 39 feet 4 inches long, 88.7 pounds per yard	1,164	2,328	....	....
2 pair of fish-plates	37½	75	....	....
8 fish-bolts, 1 inch diameter	1½	....	....	12
18 metal ties (132 pounds of steel, 110 pounds of cast-iron)	242	2,380	1,984	....
36 keys, David system	2⅕	80	....	....
Total		4,863	1,984	12

Table of ordinary track. (*Weight per yard*=388 *pounds*).

Material for 26 feet of track.	Unit weights.	Separate weights.			
		Steel.	Cast-iron.	Wrought iron.	Wood.
	Lbs.	*Lbs.*	*Lbs.*	*Lbs.*	*Lbs.*
2 rails, 60 pounds per yard	529	1,058	....	....	....
4 fish-plates	34½	69	....	....	....
16 tie-plates	33	....	528	....	....
8 fish-bolts, seven-eighths inch diameter	1	....	....	8	....
12 screws, seven-eighths inch diameter and 4½ inches long	¾	....	....	9	....
48 screws, seven-eighths inch diameter and 5½ inches long	0.8	....	....	38	....
10 ties	165	....	....	....	1,650
16 keys	2⅕	35	....	....	....
Total	....	1,162	528	55	1,650

In 1875 the company adopted a steel flange rail, weighing only 60 pounds per yard, to reduce the expense; since then the track on grades and sharp curves has been strengthened by the use of angle-bars on the inner side of the joints, ten ties per rail-length instead of nine, and iron tie-plates on each tie except those at the joints. The angle-bars are fastened to the ties by coach screws, to prevent creeping of the track. The wooden ties are creosoted with dead oil of coal-tar, at the company's works. At first the Bethell process was used, requiring 35 to 40 pounds of creosote for beech ties. Since 1876 the ties are first steamed under a pressure of five atmospheres, reducing the amount of creosote to 26 or 28 pounds and giving it a better distribution among the fibers. The oak ties are said to require 8 to 11 pounds of creosote.

NORTHERN RAILWAY.—In February, 1888, Mr. Contannin, engineer of permanent way, stated that this road had laid on its Belgian lines 1,700 ties of the Séverac type during eighteen months, and was then about to place 10,000 of these ties on its French lines. In order to establish a comparison, allowing for the great difference between the first cost of wooden ties and that of metal ties, it was hoped that a sensible economy would be realized in the maintenance expenses, but the experience was then too short to enable an opinion to be pronounced. (See Belgium.)

At the International Railway Congress held at Milan, Italy, in 1887, Mr. Kowalski stated that 1,500 ties of the Séverac type had been in use on this company's Belgian lines for about two years, and had given good results. (See "Belgium.")

SOUTHERN RAILWAY.—In September, 1889, this company reported that no metal ties have been used, even for experiment.

PARIS AND ORLEANS RAILWAY.—This company reported in March, 1888, that no trials had been made with metal ties, as the forests in the neighborhood of the railway enable the company to count upon sufficient resources for a long time to come. The woods used are oak and pine. The average price of the oak ties is 90 cents each, and their average life is fifteen to sixteen years. The pine ties, which are being abandoned, cost 66.4 cents each creosoted, and 61.4 cents treated with sulphate (presumably of copper, but not stated); the average life of the latter is ten years; the creosoted ties are of too recent date for conclusions to be drawn as to their life.

TIES.

Paulet and Lavalette ties.—These ties have been described under the heading of the State railways, on which lines they are used with double-headed rails. They are also made for flange rails, the only difference being in the form of the chair, which has a flat-top with two lugs, a key being driven between one lug and the rail-flange. The chairs are secured by three rivets. The ends of the angle-irons may be straight instead of flared out. The weight of ties for standard gauge tracks is 165 pounds, with chairs for double-headed rails, and 154 pounds with chairs for flange-rails. The ties are also made for meter gauge lines, and may be made of tee-irons instead of angle-irons if necessary (See plate No. 5).

The Brunon ties.—These ties are of pressed steel, and were invented by Mr. Bartholemy Brunon, but have, I believe, not been put in service. They are of ∩ section, narrow and deep at the middle and broad and shallow at the ends, the sides sloping up to the top table. The thickness is .32-inch throughout, and the weight about 77 pounds per tie. The rail seats are pressed up and holes are made in the sides of the elevated seat for the ends of a bent bolt which lies within the tie. For flange-rails clips are used which hold the flanges and are fastened by the bolt. For double-headed rails the same plan is adopted but the clips are larger, one bearing against the web and lower head of the rail, and the other embracing the side of the lower head. At the joints angle-bars are used having an extension of the flange bent to fit the curve of the rail-seat, the bolts passing through these flanges in the same way as through the ordinary clips. The ordinary joint bolts are used.

The Decauville ties.—These ties are used for the well-known system of Decauville's portable railways, which are for narrow-gauge plantation lines, contractor's lines, light railways, etc. They are of inverted channel irons, with the flanges bent round to close the ends. The rails are usually riveted to the ties. A line of 24 inches gauge was built on this system through the grounds of the Paris Exposition of 1889; the ties were about 3 feet 7¾ inches long, 5.6 inches wide, 1.16 inches deep, and .20-inch thick; they were spaced 10.4 inches apart, center to center, at the joints, and 25.56 inches intermediate. The rails were of flanged section, 2.4 inches high and 2.5 inches wide; each rail was fastened to the tie by three rivets, two through the inner flange and one through the outer flange. The sections of track were 16.40 feet long, with fish-plates at the rail joints. This track could carry a service load of 3 tons per axle, and a 48-ton gun was hauled over it by using four trucks with four axles each, the trucks being coupled in pairs. The line was used for passenger and freight traffic, and was operated by compound, four-cylinder, double-truck engines, weighing 11.3 tons in working order. The tramway at Laon is laid with a similar track and operated by similar engines. This line has grades of 6 per cent., with curves of 88.56 feet radius. For particulars of these two lines see Engineering News, New York, September 1, 1888, and June 1, 1889. The system is also referred to in the part of this report referring to "Light and Portable Railways."

The Goupillon ties.—These are a modification of the Vautherin type of tie, and resemble the "Post" tie; but there is claimed to be less work done on the metal than with the "Post" tie, which is bent to give the inclination to the rail. The fastenings are entirely different in character. The ties are horizontal, but at the rails the metal is thickened, and so shaped as to form a rail seat giving the desired inclination, and having a depression to receive the flange of the rail. They are 8.85 feet long, 5.2 inches wide on top, 9.2 inches wide at the bottom, 4 inches deep over all; the sides are vertical for 2.6 inches from the bottom. The thickness of the sides increases from .24 inch at the bottom to .28 inch at the top; the top table is .36 inch thick, but extra metal is added on the under side, making it .52 inch thick for a width of about 2 inches. The thickness under the rail is .76 inch. The rails are fastened by screws of different forms, the heads being wide and holding the rail-flange. They may be (1)—only long enough to screw through the thickness of the metal of the tie; or (2)—long enough to screw also through a thick iron washer inside the tie, which takes both the screws; or (3)—the ordinary long screw spikes used in European railway practice may be used, screwing into wooden blocks placed inside the tie, one under each rail. The ends of the ties are closed. For rails of 56 to 60 pounds per yard, the ties would weigh between 132 and 154 pounds each. These ties have not, I believe, been put in service.

The La Gressiere ties.—These are cross-ties of deep inverted channel section with vertical sides and a rib on each bottom edge. Along the whole length of the top table is a deep groove. A tie-plate the full width of the tie is riveted at each rail seat. The rail is fastened by broad clamps or flat spikes, which pass through slots in the tie-plate, and project down into the groove in the tie. A long taper key or cotter is driven horizontally through a slot in the lower part of each rail clamp, holding them tightly in place. The ties weigh 66 pounds for meter gauge lines, and 121 to 132 pounds for standard gauge. They are said to have been tried on the Eastern Railway, but no information respecting them has been furnished by that road.

SUMMARY OF METAL TRACK FOR FRANCE.

Railways.	Cross-ties.
	Miles.
State	31.62
Eastern	13.00
Western	2.50
Northern	5.00
Total	52.12

HOLLAND.

General Remarks.—Mr. Post, in his paper presented before the Society of Civil Engineers, France, in 1885, stated that Holland was a country not possessing any metal tie producing industry, but able to obtain plenty of cheap native and foreign timber, the latter being imported, at a low rate, by sea, river, canal, and rail. Nevertheless, nearly all the railways have been using metal ties for some years, not on account of pressure from the government, but because they are persuaded that it is to their own interest.

In Mr. Bricka's report to the Minister of Public Works of France, in 1885, is given the following table of mileages:

Table of mileage of railway track. Holland, 1878–1884.

Year.	Main lines.	Local lines.	Total track.	Wooden ties.	Metal longitudinals.	Metal cross ties.	Stone, etc.
1878	1027.34	....	1764.52	1653.54	.62	49.60	....
1879	1034.78	....	1624.40	1538.84	10.54	75.02	....
1880	1068.26	......	1718.64	1589.68	10 54	118.42	....
1881	1096.66	3.10	1778.78	1627.50	10.54	140.74	....
1882	1126.54	4.34	1922.62	1750.88	10.54	161.20	....
1883	1235.66	4.34	2066.46	1876.12	10.54	179.80	....
1884	1279.06	39.68	2204.16	1988.34	7.44	203.98	4.34

Netherlands State Railways.—The Netherlands State Railway Company, which operates the system of railways owned by the State, has had a thoroughly intelligent, careful, and practical investigation made as to the merits and advantages of different forms of ties. The company was singularly far-seeing, and when the engineer began the work he began with a careful system of records as to the track and the results obtained. Mr. Post, the engineer of permanent way, during the earlier experiments designed and adapted a special form of tie which, after some modifications shown by experience to be desirable, has been adopted as the standard form of metal tie on this railway system, and is also extensively used in other countries. This is the cross-tie of mild steel, of varying thickness and cross-section, which is now so well known as the "Post" tie.

In 1865 the company put down on the Deventer and Zwolle line 10,000 ties of the Cosijns type. (See plate No. 8.) Each tie consisted of an ordinary I beam, laid with the web horizontal (⊢⊣); under each rail was an oak block with a groove cut in it for the rail flange; the rail was fastened by two bolts. The ties were 8.85 feet long, 8 inches wide, and weighed 124.74 pounds each. The results on the whole were satisfactory. The cost of packing had not been much higher than with wooden ties, and the renewals of the wooden blocks had not cost more than those of wooden ties. Experience showed, however, that the fastenings were defective, the bolts being too long and permitting a transverse sliding of the blocks with the rails on the tie. For this reason it was found better to attach the rails directly to the metal ties. In 1880 the company again took up actively the question of metal track, and at that time Mr. Post was directed to investigate the results of trials made by other companies. Acting upon his report the company decided to select the type of tie which seemed the best adapted for the purpose, to place it in the track, and to observe it carefully; also, to lay a section of track on wooden ties, in continuation of the track on metal ties, and under the same condition of line and traffic. It was further resolved that the following year a second type of metal ties should be selected, profiting by the experience of other countries, and endeavoring to avoid any defects observed in the first type, in order to be able to form opinions as to the comparative merits of the different types. In 1886 the company had, besides the types of composite (iron and wood) ties of Cosijns and Renson, six types of metal ties and three types of fastenings. While continually improving the ties, it was decided in 1884 to adopt the latest types, as improved by Mr. Post. This track consisted of steel cross-ties of varying section, weighing 110 to 121 pounds, with bolts 0.88 inch diameter, having eccentric necks, steel clamps for the rails, and plain Verona nut locks.

The trials were all made on the Liege and Luxembourg line. The several types of ties were as follows: (See plate No. 8.)

(0) Oak ties of half-round section, 8.53 feet long, 4 inches wide on top, 11 2 inches on the bottom, 5 inches deep. There were 1,120 laid in 1881.

(I) Rolled iron ties of inverted trough section ("Vautherin" type), weighing 88 pounds each; 7.71 feet long, 9.4 inches wide at bottom; they were bent up at the end at an inclination of 1 in 20, and the extremities were closed. In 1881 there were 4,133 of these laid.

(II) Rolled iron ties of similar section, weighing 104 pounds each; 8.20 feet long, 8.8 inches wide at bottom over the flanges; the ends were inclined at the rail seats and then curved down; the extremities were closed by angle-irons and two pieces of angle-iron were riveted inside at the middle 20 inches apart. In 1882 4,001 of these were laid.

(III) Mild steel ties of inverted channel section, with wide horizontal flanges at the bottom (Haarmann type); they were of the form used on the Prussian State railways and weighed 110 pounds each; 8.20 feet long, 10 inches wide over the flanges, and of similar longitudinal section to No. 2. In 1883 2,089 of these were laid.

(IV) Mild steel ties similar to No. 3, also as used on the Prussian State railways, but weighing 114.4 pounds each. At the middle, and placed 16 inches apart, were two riveted pieces of Z-iron. In 1883 2,090 of these were laid.

(V) Mild steel ties of inverted trough section ("Vautherin" type), 8.53 feet long, 8.8 inches wide at the bottom, weighing 95.5 pounds. The tie was horizontal, but at the rail seats for a distance of 10 inches the metal was pressed up cold to the desired inclination and at the end of the rail seat the metal sloped back to the normal level of the tie (Hosch-Lichthammer method). In 1884 11,680 of these were laid.

(VI) Mild steel ties of inverted trough section, but of polygonal instead of pyramidal section ("Post" type). They were rolled with varying section and thickness and an inclination of the rail seats. The bottom was horizontal, with the closed ends projecting below it. They were 8.36 feet to 8.7 feet long, 9 inches wide at the bottom, 3.3 inches deep; 110 pounds weight, or 121 pounds for curves, grades, etc. The price in May, 1886, was $21.2 per 2,200 pounds at the works. All the ties, whether for tangents or curves, had the four holes drilled in identically the same places. In 1884 and 1885 47,338 of these ties were laid, and 50,000 in 1886.

The fastenings were as follows: (See plate No. 8.)

(A) Iron bolts, .76 inch diameter, with eccentric necks, giving .08 inch to .56 inch adjustment of gauge. Iron clamps and Verona nut locks were used. These were used in 1881, 1883, and 1884 for types of ties I, III, IV, and V.

(B) Steel bolts of Ibbotson's type, having ⊥-heads. A square washer received the thrust of the rail flange and gave an adjustment of gauge of .08 inch to .64 inch; the rail clamp was of channel shape, one leg resting on the rail flange, and the other on the tie, outside of the gauge plate. This is the Roth and Schuler system and was used in 1882 for ties of type No. II.

(C) Steel bolts .88 inch diameter, with eccentric necks, giving an adjustment of gauge of .32 inch to .64 inch. The steel rail clamps had the upper surface roughened to give a grip to the Verona nut lock. A few bolts of special dimensions were used at the extremities of curves. These were laid in 1884, 1885, and 1886 with ties of type No. VI.

During 1886 and 1887 three more types of ties were designed by Mr. Post, as follows: (See plate No. 8.)

(VII) This type was in general similar to No. VI but was narrower and deeper at the middle than at the ends, the bottom swelling downward and the sides at the middle flaring inward so that the bottom edges nearly met. It is more easily laid in the ballast, but is more difficult to manufacture.

(VIII) This is similar to No. VII, but at the narrow part the sides flare outward in Λ-shape; bottom width 9.4 inches at ends and 5.4 inches at the middle. Types VIII and IX are easy to manufacture. The object of narrowing the tie at the middle is to throw the principal bearing at the rail seat to insure the stability of the track; it also increases the rigidity of the tie.

(IX) This is similar to No. VIII but has the bottom horizontal, the increased depth at the middle being obtained by curving up the top table.

At the end of 1886 there were 134,000 metal ties in service, the weight, date, class, etc., of which are given in a table, which will be found a few pages further on, in the company's report to the Railway Congress of 1887.

Of 124,000 ties laid since 1880, not one had to be removed. The ties of types Nos. VI to IX, being of varying section and thickness, corresponded to weights of 126.50 and 139.15 pounds of ties of uniform thickness, an economy of 15 per cent. In the Dutch contracts, official account is taken of this difference in weight to compare the behavior of ties of varying section with that of ties of uniform section; it is the price per tie, with an equal section under the flange of the rail, which guides in the selection. The price paid by the company previous to

1887 for steel ties of varying section, not narrowed at the middle and not tarred, was about $20 per 2,200 pounds at the works. The price per tie was about $1.10 to $1.20.

The following table gives the results of these trials, showing cost of maintenance; the prices do not include first cost. Twelve of the sections are in rough country, with a traffic of twenty-five or more trains per day; the other nine sections are in flat country, with fourteen trains per day. All are single track. The varying conditions of grades and curves appear to have no particular effect upon the cost of maintenance, but the cost is affected materially by the amount of traffic, being much higher on the divisions with twenty-five trains than on those with fourteen trains. Respiking on the trial divisions laid with wooden ties was carried on in 1886 and 1887, so that the cost would not be less for 1887, and it would tend to increase with the age of the wood. None of the oak ties had needed renewing, but it soon became necessary, and this work, apart from the cost of new material, increased the maintenance expenses considerably. On the other hand, these expenses with metal track were generally highest during the first year of service, gradually diminishing thereafter.

Cost of maintenance on trial tracks with wooden and of metal ties, Netherlands State Railway Company.

Trial number.	Trains per day.	Section of line.	From—	To—	Grade in millimeters per meter.	Radius of curves in meters.	Length of trial in meters.	Number of ties.	Types.	
									Ties.	Fastenings.
	1	2	3 *Kilom.*	4 *Kilom.*	5	6	7	8	9	10
1	25	Liége-Tongres	15.620	14.612	12.0	500	1.008	1,120	Oak.	Spikes.
2	25	... do	16.666	15.620	12.0	750 straight.	1.046	1,133	I.	A.
*3	25	Bilsen-Hasselt	41.093	40.170	1.2	straight.	0.923	1,000	I.	A.
6	25	Liége-Tongres	7.946	7.432	16.0	1,000	0.514	600	II.	B.
7	29	Liers-Flémalle	1.831	1.393	level.	1,000	0.438	500	II.	B.
8	25	Tongres-Bilsen	25.031	24.570	8.0	straight.	0.461	500	II.	B.
*9	25	Bilsen-Hasselt	43.625	43.349	4 0	straight.	0.276	300	II.	B.
11	25	Liége-Tongres	3.790	3.640	16.0	350	0.150	201	II.	B.
12	25	....do	12.787	12.528	13.0	500	0.259	300	II.	B.
14	25	....do	4.602 3.640	3.790 2.836	16.0	350	1.016	1,328	III. IV.	A.
17	25	....do	12.528	12.315	13.0	500	0.213	250	IV.	A.
21	25	....do	4.412 4.755	4.302 4.748	16.0	530	0.117	200	VI.	C.
22	25	....do	8.000	9.000	16.0	1,000	1.000	1,081	VI.	C.
4	14	Hasselt-Wychmael	22.238	21.130	2.9	straight.	1.108	1,200	I.	A.
*5	14	Wychmael-Achel	32.673	31.940	3.4	straight.	0.733	800	I.	A.
10	14	Hasselt-Wychmael	8.408	7.301	3.9	straight.	1.107	1,200	II.	B.
13	14	.. do	1.562	1.218	6.5	500	0.344	400	II.	B.
15	14	.. do	1.218	0.765	6.5	500	0.453	500	III. IV.	A.
16	14	Achel-Eindhoven	47.334	47.795	0.8	2,000	0.461	500	III.	A.
18	14	....do	47.795	48.256	level.	straight.	0.461	500	IV.	A.
19	14	....do	46.868	47.334	0.8	straight.	0.466	505	V.	A.
20	14	....do	52.709	52.032	1.0	2,000 straight.	0.677	735	VI.	C.
23	14	....do	57.342.50	56.425.9	1.0	2,000	0.083.40	93	VIII.	C.
24	14	....do	57.425.95	57.509.10	1.0	2,000	0.083.15	93	IX.	C.

Cost of maintenance on trial tracks with wooden and of metal ties, etc.—Continued.

Trial number.	When laid.	Date when observation commenced.	Days in service.		Cost of maintenance in francs per kilometer per day.							
			From beginning observation to January 1, 1888.	1887.	1881.	1882.	1883.	1884.	1885.	1886.	1887.	Average from beginning observation to January, 1888.
	11	12	13	14	15	16	17	18	19	20	21	22
1	1881	July 1, 1881	2,375	365	0.159	0.217	1.226	0.396	0.493	1.101	0.423	0.605
2	1881	....do	2,375	365	1.128	0.423	0.576	0.195	0.086	0.538	0.842	0.650
*3	1881	Sept. 1, 1881	2,313	365	1,930	0.829	1.884	0.256	0.901	0.383	1.135	0.952
6	1882	Jan. 1, 1882	1,826	365	....	....	1.214	0.489	0.638	1.112	0.552	0.801
7	1882	...do.......	1,826	365	....	....	1 582	0.277	1.160	0.494	0.573	0.817
8	1882	....do.......	1,826	365	....	....	1.676	0.533	1.253	0.118	0.046	0.725
*9	1882	...do	1,826	365	....	....	1.687	0.861	0.953	0.278	0.625	0.881
11	1883	Oct. 1, 1882	1,553	365	....	....	0	1.084	1.974	1.187	1.660	1.389
12	1883	....do	1,553	365	....	......	0	0.891	0.465	0.264	0.746	0.557
14	1883	....do	1,553	365	....	....	0	1.647	1.792	0.867	1.610	1.392
17	1883	do	1,553	365	....	....	0	1.132	1.111	0.498	1.000	0.879
21	1885	Apr. 1, 1885	1,005	365	....	....	....	....	0.036	0.078	0.983	0.495
22	1887	June 1, 1887	214	214	......	......	....	....	......	.....	0	0
4	1881	June 15, 1881	2,390	365	06.635	0.595	0.614	0.198	0.156	0.418	0.297	0.407
*5	1881	Sept. 1, 1881	2,313	365	1.584	1.027	0.790	0.326	0.536	0.569	0.227	0.632
10	1882	Jan. 1, 1882	1,826	365	....	......	1.077	0.475	0.329	0.503	0.595	0.596
13	1883	Sept. 15, 1883	1,569	365	....	....	0	0.433	0.438	0.879	0.583	0.543
15	1883	....do	1,569	365	....	......	0	0.246	0.412	0.258	0.429	0.313
16	1883	Mar. 1, 1884	1,401	365	......	....	....	0.311	0.143	0.329	0.802	0.421
18	1884	....do	1,401	365	....	....	....	0.299	0.372	0.533	0.651	0.471
19	1884	....do	1,401	365	....	....	....	0.551	0.897	0.277	0.492	0.554
20	1885–'86	June 1, 1886	579	365	....	....	....	......	......	0.144	0.252	0.212
23	1887	Sept. 1, 1887	122	122	....	....	....	....	......	......	0	0
24	1887	.. do	122	122	....	....	....	....	......	......	0	0

*Marshy ground.

Remarks.—These trial-lengths are on single-track road. First group, 25 to 29 trains per day; second group, 14 trains per day. Rails, 76.45 pounds per yard; steel angle splice bars. Ballast—gravel, sand, and cinder. Heaviest engine on these lines, 50 tons, with 13½ tons on the heaviest axle; heaviest engine on other lines, 68 tons with 13.9 tons on the heaviest axle. Speed up to 50 miles per hour (on some parts 60 miles per hour). A day's maintenance per man costs 2.19 francs; the results of columns 15 to 22 may be transformed into days by dividing by 2.19. The figures in columns 15 to 22 give the expense for work of maintenance, not the expense for purchase of new spikes, bolts, washers, etc. Not one of the metal ties in this table, nor of the 124,000 steel ties in use on other lines of the Netherlands State Railway Company, has broken in the track.

Mr. Renson, engineer of the Liege and Luxembourg division, has stated that the actual cost of maintenance per kilometer for track on metal ties, after three and a half years' service, was equal to that for oak ties of the same age; the cost of the latter would, however, go on increasing until renewals became necessary, as they would ere long, while the cost for metal ties would diminish, owing to the settling together of the pieces. The ties of type No. I tended to shift, and after some months of service a number of bolts worked loose in a very short time. The shifting of the ties was prevented by filling in the ballast on the outside of the track to the level of the rail-heads. The use of steel nut-locks prevented the loosening of the bolts, so that only one inspection and tightening per year was needed. Experience with some nut-locks of poor quality led Mr. Post to the opinion that such were worse than none at all; he prefers the nut-locks with one spiral turn to those with two turns, the latter giving less pressure and not retaining their spring. The labor of maintenance was about .35 day's work per day-kilometer; the labor on long sections of line with uniform types of ties was even less. The maintenance includes lining, raising, tamping, trimming, inspection of nuts, etc. The cost of renewals was *nil*, not one tie having been broken. A gang of four men, working two hundred and fifty days per year, can maintain 4.96 miles of metal track in good condition. Heavier ties are used on curves, owing to the greater wear caused by the thrust of the rail-flange. In order to test the comparative merits of the rail fastenings used with metal and with wooden ties, an experiment was made in 1885 by placing wooden packing pieces under rails on both forms of ties; after four months' service it was found that those on the metal ties were simply compressed, while those on the wooden ties were crushed and bruised, showing evidence of a hammer action of the rail, due to the inefficient holding of the spikes.

The standard tie of the Post type is 8.36 to 8.7 feet long; at the middle it is of ∧ section, 4.48 inches deep, top radius 1 inch, 4¼ inches wide inside at the bottom and 5.4 inches wide over all at the bottom; the sides slope about 1 to 3; average thickness .24 inch. At the rail-seat the section is polygonal, 4.4 inches wide on top, 10.20 inches wide over all at the bottom, 2.98 to 3.02 inches deep; thickness of sides from .24 and .28 inch at lower part to .32 to 36 inch at upper part; thickness of top table .36 to .40 inch, and .48 to .52 inch at the middle, the thickness being increased at the bolt holes. At the extremities of the rail seats, the section is of rounded trough form, 4.96 inches wide on top, 9.4 inches wide over all at bottom, 2.56 to 2.60 inches deep, 1.20 to 1.52 inches radius of top corners; thickness from .24 and .28-inch at sides to .32 and .35 at middle of top table. The top table is sloped up at the rail seats to give the rails an inward inclination; it slopes down again to the horizontal and is bent down to close the end, projecting below the body of the tie. On the bottom edges are ribs of triangular section about .60 or .72 inch deep, and projecting .52 inch beyond the face of the side of the tie; these ribs prevent damage to the edge in tamping, and by lowering the neutral axis give additional stiffness, while they also make the section easier to roll. The bolt holes are .92 by 1.24 inches, oblong, with rounded corners. The weight of the tie is about 117.7 pounds. The rail clamps are 2.4 by 2.6 inches, with a .96 inch bolt hole; one end of the clamp rests on the rail flange and the other end on the tie; the greatest thickness is .96 inch; the top is toothed. The plain Verona nut locks are of .24 by .24 inch square section, .47 to .51 inch wide over the spiral, and .94 to 1.01 inch inside diameter; the grooved Verona nut locks are of .26 by .26 grooved section, .51 to .58 inch wide. The bolts are .88 inch diameter, with Whitworth thread; they are 3.08 inches long under the head; the head is 1.52 by 1.84 inches in size and .56 inch thick; the eccentric neck under the head is .88 by 1.20 inches, oblong, with rounded corners. The nuts are of hexagon shape, 1.08 inches deep, with the lower face toothed. Two forms of bolts are used, type "A" being for three different adjustments of gauge, and type "B" for the points of change from one of these variations to another, as at the extremities of sharp curves. For the convenience of the trackmen, the type "A" bolts have a piece chipped off the edge of the end, while those of type "B" have a larger piece cut off and have also a groove cut across the end; these marks not only serve to distinguish the two classes of bolts, but by their position enable the trackmen and inspectors to see at once the gauge to which the rails are set. The "A" bolts have the eccentric neck projecting on one side only of the shank, the neck being .88 by 1.20 inches, giving a projection of .32 inch; the "B" bolts have the neck the same size but projecting .24-inch on one side of the shank and .8 inch on the other. The weight of the bolt nut is about 1.1 pounds.

The weights of the track are as follows:

Material for 29.54 *feet of track.*

	Pounds.
2 rails 29.52 feet long, 68 pounds per yard	1,334.52
2 pair splice bars, 46.2 pounds per pair	92.40
8 splice bolts, with nuts and washers, 1.65 pounds each	13.20
40 rail clamps, .88 pound each	35.20
40 fastening bolts, with nuts and washers, 1.1 pounds each	44.00
10 steel ties, 117.7 pounds each	1,177.00
Total	2,696.32
Weight per yard	273.87

Material for 39.38 *feet of track.*

2 rails, 39.36 feet long, 76.45 pounds per yard	2,006.40
2 outer splice bars, 25.08 pounds per pair	50.16
2 inner splice bars, 25.96 pounds per pair	51.92
8 splice bolts, with nuts and washers, 1.32 pounds each	10.56
52 rail clamps, .88 pound each	45.76
52 fastening bolts, with nuts and washers, 1.1 pounds each	57.20
13 steel ties, 117.7 pounds each	1,530.10
Total	3,752.10
Weight per yard	285.75

Mr. Bricka, in his report to the minister of public works (France) in 1885, spoke very highly of the Post ties, and stated that the weeds growing in the ballast at certain points were evidently from the preceding year (his inspection was made in April, 1884) and proved that frequent ballasting was not necessary. He did not approve of the reduction of the thickness of parts of the tie in order not to exceed a weight of 110 pounds, and he preferred to the bolts with eccentric necks, used for fastenings, the Ruppel clamp fastening or the Heindl clamp, which is a modification of the former (see "Germany," Prussian State Railways; and "Austria," State Railways). Since the date of Mr. Bricka's report, the weight of the tie has been increased as noted; and it will be noticed later on that Mr. Post has now, in his latest type of tie, abandoned the eccentric neck bolts and adopted the Roth-Schuler system of fastening, type "B" (See plate No. 9); he still, however, allows the bolt to resist the lateral pressure, instead of transferring some of it to the tie by using a clamp with a lug fitting into a hole in the tie, which is the feature which Mr. Bricka considers to be advisable. The report gives the following statement of the track in 1884:

	Miles.
Main line	851.88
Total track	1,286.50
Wooden ties	1,267.28
Metal ties	14.88
Stone, etc	4.34

The report made to me in March, 1888, by Mr. Kalff, chief engineer, gave the following particulars:

The system comprised 910 miles of line, of which 91 miles were laid with metal ties. The traffic consisted of passenger and freight trains, the speeds ranging from 20 to 47 miles per hour; the engines weigh from 50 to 68 tons in working order, with a maximum of 7 tons on each driving wheel. The "Post" ties are of mild steel, (Thomas, Martin, or Bessemer); they are spaced 3 feet 2 inches apart at the widest spacing, and at the suspended joints they are 1 foot 5 inches apart, so that the ends of the fish-plates butt against the rail clamps and prevent creeping. The ties are not tarred or otherwise treated. They are manufactured by the Hoerde Steel Works, Hoerde, Germany, and the Angleur Steel Works, Angleur, Belgium. They cost $22 per ton at the works, not tarred, and the fastenings cost 22 cents per tie. The maximum adjustment of the gauge is a widening of five-eighths inch. Of the 10,000 ties ("Cosijns" type) laid in 1865, 9,550 were still in use and were expected to last twenty years more. The ballast is of gravel, sand, and ashes; it fills the hollow of the tie and makes a compact mass. The width of road-bed at subgrade is 32 feet 9¾ inches; it is crowned 7⅞ inches, so that the ballast is 17 $\frac{11}{16}$ inches thick in the middle and 27⅓ inches thick at the sides; the ballast is brought up level with the top of the rails, the rail being left clear on both sides, and has side slopes of 2½ to 1. The ties were adopted on account of durability, economy, and security; the results, have been satisfactory, and there has been no trouble with maintenance, rail attachments, or from breakages; of 162,634 ties laid, not one had been broken. The use of the "Post" tie was being extended on the line. The climate is damp, but the loss of weight by rust is only about 4 per cent. in twenty years. The oak ties cost $1 each. The minimum radius of curves where these trials were made is 1,148 feet; maximum grade 1.6 per cent.

The track of this railway consists of steel flanged rails, weighing 68, 76.45, and 80.5 pounds per yard; the latter are 5.55 inches high, with a flange 4.08 inches wide; the head is deep, with vertical sides, 2.4 inches wide, 8 inches radius of top table, .56 inch radius of top corners. The joints are spliced with angle bars having short flanges, and the outer bar, with the heaviest section of rail, projects up the side of the rail head. The bars are 30.4 inches long; the inner holes are spaced 4 inches and the outer holes 7.8 inches apart, center to center; the holes in the outer bar are 1.12 inches square, with rounded corners, those in the inner bar are 1.08 inches diameter. The joint bolts are of steel, 1 inch diameter, 4.24 inches long under the head. With wooden ties, spikes .56 by .64 inch section, and 6.48 or 5.8 inches long are used. At the joint ties the rail rests on a grooved iron tie-plate, 7.2 inches square, with 4 spike holes; the spikes engage with notches in the angle bars. The wooden ties are spaced 22 inches apart, center to center, at the joints, and 27.12 to 39.2 inches apart intermediate, there being 10, 11, or 12 ties to a rail length of 29.52 feet. A space of about .28 inch is left between the ends of the rails. The steel ties are spaced with 10, 11, or 12 to a rail length of 29.52 feet; they are about 18.08 inches apart, center to center, at the joints, and 28.68 to 39.2 inches apart intermediate. With rails 39.36 feet long, 13 ties are used; they are spaced 24.08 inches at the joints, 34.76 inches next to the joints, and 38.64 inches intermediate. Splice bars 30.4 inches long are used, with notches in the flanges to admit the rail clamps.

The latest type of "Post" tie, as modified in 1889 (See plate No. 9), presents some changes from the previous type which had been most extensively used. The bolt holes are circular instead of oblong, and the extra thickness of metal at the hole is given a channel form to fit the heads of the bolts and prevent them from turning. The method of fastening is also different, being a return to type "B," already described, being the Roth-and-Schuler system.

A square gauge-washer is used, with the bolt hole .92 inch diameter, so placed as to be .24, .32, .48, and .56-inch from the sides, thus permitting a very close adjustment of gauge according to the position of one, two, three, or four of the washers on each tie. The rail flange butts against this washer. The clamp is of channel form, one side resting on the rail flange and the other on the top of the tie, and prevents the clamp from turning. A grooved Verona nut-lock is used between the nut and clamp. The washer is 1.72 inches square and .56 inch thick. The clamp is 3.16 by 2.48 inches, .56 inch thick, and 1.24 inches deep over all; its hole is 1 by 1.32 inch oval. The bolt is .88 inch diameter in a .92-inch hole in the tie; it is 3.52 inches long under the head, with Whitworth thread; the head is 1.52 inches square, .56 inch thick. The tie is 8.36 to 8.7 feet long. At the outer part of the rail seat it is 3.78 inches wide on top, 9.4 inches wide on the bottom, 3.28 to 3.32 inches deep, .24 to .36 inch thick at sides, .36 to .40 inch on top, .48 to .52 inch at middle of top table. At the rail seat it is 4.08 inches wide on top, 2.98 to 3 inches deep, in other respects of similar dimensions as above. At the inner side of the rail seat it is 5.04 inches wide on top, 2.56 to 2.60 inches deep, in other respects as above. At the intermediate parts and at the ends it is the same width and depth, .24 and .28 inch thick at the sides and on top. The cross-section is polygonal, each side having two planes, and the angles are rounded off by curves of 1.12 to 1.52 inches radius. At the middle the section is narrow and deep, either the top or bottom of the tie being horizontal; the section here is Λ-shaped with the top bent to a radius of 1 inch, and the sides sloping at an inclination of 1 to 3; the depth is 4.6 inches, width at bottom about 5 inches, and the thickness of the sides .24 inch. The sides of the channel in which the bolt heads fit are .24 inch deep. A heavy rib of triangular section is on the lower edges of the sides.

Report of the International Railway Congress, 1887.—The following is a translation of the report presented by this company at the International Railway Congress, held at Milan, Italy, in 1887:

> The experience with the 10,000 "Cosijns" cross-ties, laid in 1865, has brought out four facts: (1) There is no fear of rust; after twenty-two years' service the weight has only diminished 4 per cent. The ballast is of gravel and sand; on other lines it has been observed that ordinary ashes do not corrode the iron to a greater extent. (2) While in general the interposition of plates between the rail and the tie may not be desirable, as by such interposition the bolt permits a transverse motion of the rail on the tie, the gauge is fairly well maintained. (3) The bolt gives good results as a fastening of the rail to the tie; while the iron of the bolts was only .68 inch thick,

there were still a number of bolts in use after twenty-two years' service. (4) A good tie lasts for a long time. After twenty-two years' service on the line between Deventer and Zwolle, with an average traffic of twelve trains per day (actually sixteen trains per day), there are in service and in good condition 9,547 ties (95½ per cent.), and there is no reason to expect that they will not last twenty years more. The 4½ per cent. taken out would still have been in service if the splicing of the old rails had been sufficient. These results with an old type of tie promise well for the latter types of improved ties. The metal ties taken out have brought seven times the price of old wooden ties.

The result of this first trial encouraged the company to commence in 1880 a methodical and practical study of the question of metal ties, and it now presents some of the results of this work. Information was acquired as to the results obtained abroad and in Holland both as regards the track and the manufacture. In order to keep within the limits of practice and economy it was decided that the first cost of the ties to be tried should not exceed 25 or 50 per cent. above that of oak ties, this difference representing the general valuation of the former over the latter. Each year a certain number of ties were put in service, and it was the endeavor each year, in spite of the favorable impression from the beginning, to improve upon the tie and fastening of the preceding year, avoiding defects observed and profiting by the experience acquired, by the experience of other companies, and by the progress effected in manufacture. Of each of the types in service special observation was taken of the maintenance, noting minutely every hour of work and keeping record of each piece (spikes, bolts, etc.) broken or replaced. As a base of comparison a new track was established on a trial section of line with good oak ties (presenting 4 inches wide of heart wood under the flange of the rail), under ordinary conditions of operation; this track was carefully maintained and the maintenance expenses noted in the same way as with the experimental sections of track with metal ties. Proceeding in this way the company put ties in service as follows up to January 1, 1887:

Year.	Number.	Character.	Weight (each).
			Pounds.
1865	*10, 000	Cosijns	123. 64
1881	*4, 133	Type I	88
1882	*4, 001	Type II	103. 84
1883	†2, 089	Type III	110
1883	†2, 090	Type IV	110
1884	†11, 680	Type V	95. 48
1884 to 1887	†100, 000	Types VI to IX	‡110 to 121
Total	134, 000		

* Iron.
† Steel.
‡ Corresponding to 126.5 to 139.15 pounds of uniform section.

None of the 124,000 ties laid since 1880 have been taken out of the track.

The results of the observations of twenty-one trials made up to January, 1887, are presented in the table. [This table has already been given, as extended by Mr. Post later to include the year 1887.—E. E. R. T.] Columns 1 to 14 show the conditions of the track and traffic, the types of ties and fastenings and the duration of the observation; columns 15 to 21 show the cost of maintenance in francs per day and per kilometer; these prices do not include the first cost, but the labor of renewals. The sections are grouped in two parts. The first group includes twelve sections in uneven country (columns 5 and 6) where the number of trains per day is twenty-five or more (column 1); the second group includes nine sections in flat country, with only fourteen trains per day. A record of thirty years of observations and for several kilometers would give, it is true, more conclusive figures, but while awaiting more complete data we can already make the following observations, taking into account the facts observed and the records kept of the trials given in the table.

(1) The sections Nos. 11 and 14 are on a curve of 1,148 feet radius and a grade of 16 millimeters per meter (1.6 per cent.). The oak ties formerly used here had to be re-spiked every year owing to the motion of the rail flange which cut into the spikes .12 to .16 inch per year. Some ties of Type III, with attachments "A," however, taken out of the curve for the inspector after 1188 days of service (1553 days in 1887), showed only .08 inch of widening of gauge, each of the bolts being cut into .04 inch by the flange of the rail. In other curves of larger radius than 1,148 feet there is no cutting of the bolts. The top table of the ties of Type III taken out of this curve only presented a very slight wear and the bolt holes did not show any ovalisation or enlargement. These ties are of steel; iron does not so well resist the wear at the rail seat and bolt holes. In view of the very unfavorable circumstances under which these ties were laid, we need have no fear as to these two kinds of wear, but at the same time it is reasonable to put thicker ties on curves and to space them closer together. The cost of maintenance in this part has never reached 2 francs per day per kilometer (64.5 cents per mile per day).

(2) As regards the work of maintenance, sections Nos. 3 and 9 are under equally unfavorable conditions, the country being marshy.

(3) The average cost of maintenance on four sections, Nos. 2, 3, 4, and 5, which have had about the same service as section No. 1, with wooden ties, does not differ sensibly from the cost on section No. 1. In order to judge of the importance of this result it is necessary to bear in mind the following particulars: (*a*) Type I of the metal cross-ties is used on these four sections and is the most primitive of the forms used, each of the other types, II to VI, being an improvement upon the preceding. It may, therefore, be supposed that any of the other types would have given still better results. (*b*) The adzing and re-spiking of the wooden ties, which commenced in 1886, must be continued in 1887, so that the maintenance expenses for this section will be as high as in 1886, and it may be presumed that it will increase with the age of the wood. (*c*) The maintenance expenses of sections Nos. 2 to 5, however, show a tendency to decrease with the consolidation of the track. (*d*) Since the oak ties were laid in 1881 not one has been renewed, which proves that they are of excellent quality; renewals must soon begin, however, and will add considerably each year (apart from first cost) to the expenses of work of maintenance.

(4) The average maintenance expenses per day per kilometer of sections Nos. 6, 7, 8, 12, and 17 does not exceed .89 franc, and that of sections Nos. 10, 13, 15, 16, 18, and 19 is about .60 franc, although these sections only date from 1883 and 1884.

(5) The observations of Type VI are too short to judge of its value by the maintenance expenses. The company has also put in service in 1886 and 1887 ties of Types VII, VIII, and IX. [Already described.—E. E. R. T.]

(6) The putting in service successively of sections Nos. 2 to 21 not having up to the present time occasioned a higher rate of maintenance expenses than would have obtained with wooden ties, it may be admitted that a company which puts in every year a certain number of metal ties of reasonably good design will not increase its maintenance accounts and need not increase its staff.

(7) A piece of track near Liege (with twenty-five trains per day), 984 feet long, on a curve of 1738.40 feet radius and a grade of 1.6 per cent., laid with ties of Type III, was left, after having been carefully packed, for forty months (three and one-third years) without packing or surfacing or any other work except inspection of the nuts. At the end of that period the track was still in good condition. This proves that a good metal track, once well laid and packed, does not require more inspection or maintenance than a track on wooden ties; on the contrary it would be dangerous to leave a track on wooden ties for three and one-third years unattended to, under these conditions.

(8) The diagrams of the gauge-registering apparatus are much more regular for tracks on metal ties of Types I to IX than for those on wooden ties, even when the latter are new.

(9) The inclination of 1 in 20 of the rail, which is often disturbed on wooden ties by the turning outward of the rail, is maintained invariable with metal ties of Types I to IX.

(10) The lateral displacement of the tie by the traffic is *nil*, or insignificant, even on sharp curves, provided that the tie is properly closed at its extremities. It has been observed that intermediate closings, as in Types II and IV, are absolutely superfluous, as Types I and III, without these intermediate pieces, do not shift.

(11) The re-adzing of the rail seats and re-spiking, in 1886, of some of the oak ties of section No. 1, necessitated the replacing of two tie-plates and four hundred and eighty spikes; the renewal of attachments of metal ties is insignificant, especially for Type "C."

(12) Rolled iron is not recommended as a material for ties; mild steel of good quality is the best material in every respect for manufacture, inspection, solidity, and durability.

(13) Track laid with rails breaking joint has given, with angle splice bars, good results, especially on curves.

(14) The joints should be suspended and spliced by angle bars.

(15) The Types VI, VII, VIII, and IX leave nothing to be desired. The hollow trough packs itself easily in any ballast; gravel, sand, ashes, or broken stone. Generally the ballast forms a compact core adhering to the interior of the tie, filling it entirely at the rail seat, and increasing its base. If the packing does not extend more than 16 inches on each side of the flange of the rail, the tie can never "dance," and the shape of the tie tends to drive the ballast towards the rail seat.

(16) The track men, who are generally opposed to metal ties at first, very soon become accustomed to them. It is easy to obtain an excellent track, even with inexperienced men, by giving them proper instructions.

(17) To test the bending which ties of Type VI would sustain without cracking in case of derailment, the company made a series of tests of bending the tie cold at each side of the rail seat; punched ties, not annealed, of varying section, would bend 75 degrees before cracking; it was concluded that with steel, the form of the tie and the punching (with round corners) in question, annealing is not necessary, the deformation of the tie in case of derailment never being 75 degrees at the bolt holes. Ties punched and annealed would bend (like ties not punched and not annealed) 180 degrees without cracking. In view of this remarkable result the company considered annealing to be desirable, but with the condition that it did not cost more than a few centimes per tie.

We end this description by the calculation of the normal maintenance in a case determined by the engineer of the system on which the twenty-one trials have been made: "A track of Type VI, C fastenings, in the conditions of line, ballast, and operation of the Liege-Hasselt section, can, after 3 years for consolidation, be properly maintained at the rate of 100 days' work per year per kilometer. A gang of four men, working 250 days per year, can then, giving 50 days to other work, maintain in good condition, 4.96 miles of track."

For further details of the work done on this system, see the paper by Mr. Post on "Maintenance expenses of track on wooden and metal ties," printed in my preliminary report (Bulletin No. III).

HOLLAND RAILWAY.—The Holland Railway Company (or Dutch Railway Company), first used "Vautherin" ties weighing 72.6 pounds each, curved to give the rails an inward inclination, and open at the ends; the rails were fastened by gibs and cotters, but the cotters worked loose, being too narrow and not having sufficient bearing surface. The company now has mild steel ties of Vautherin section, as this is found to be the best shape for sand ballast (See plate No. 11). The ties are of two forms, joint and intermediate; all are 8.53 feet long. The joint ties are 6.4 inches wide on top (of which 4 inches are slightly thicker and form the rail seat), 8.72 inches wide inside at the bottom, 11.2 inches wide over the flanges, and 2.64 inches deep over all; the thickness is .24 inch at the sides and top, .32 inch at the rail seat, and .72 inch at the middle of the rail seat, where there is a rib 1.2 inches wide on the under side of the top table. The weight is about 112.2 pounds. The intermediate ties are 3.2 inches wide on top, 6.8 inches wide inside at the bottom, 9.2 inches wide over the flanges, and 2.64 inches deep; the top table is .52 inch thick for a width of 1.36 inches. The ends of both forms are closed by riveted angle pieces. The tie is horizontal, but at each end is a tie plate, 11.6 by 2.8 inches, secured by two rivets. This plate has an inclined seat for the rail, and has a rib on each side parallel with the rail flange. This rail is held by a T-shaped clamp on each side; one side of the head of the clamp rests on the rail flange and the other side on the rib of the tie plate, with the lower part between them; a ⊥-headed bolt passes up through the tie plate and clamp. The shape of the tie allows for an adjustment of gauge. The ties are dipped cold in tar. For the light line from The Hague to Scheveningen a lighter tie of Vautherin section is used, with a bolt fastening similar to that of the Left-Bank-of-the-Rhine Railway. (See "Germany.") For lines of which it owns the concessions the company has abandoned wooden ties, but Mr. Bricka, in his report in 1885, stated that it had not received permission from the State to substitute metal for wood on the lines of which it is only the lessee. With the track on this road Mr. Bricka mentions a straight splice bar of three thicknesses, similar to the Samson bar used in this country. A later form of tie used is without the horizontal flanges, but has a rib on the inner side of each bottom edge. For main lines they are 5.84 inches wide on top, 7.2 inches wide inside at the bottom, and 8.8 inches wide over all, 3.2 inches deep, .24 inch thick on the sides and .32 inch on top. For local lines they are 4.4 inches wide at top, 5.4 inches wide inside at bottom, 6.64 inches wide over all, 2.4 inches deep, .20 inch thick on the sides, and .24 inch on top.

Mr. Bricka, in his report to the minister of public works (France) in 1885, gives the following statement of the track of this road at the end of 1884:

	Miles.
Main lines	175.40
Local lines	35.34
Total track	496.62
Wooden ties	417.26
Metal longitudinals	.62
Metal ties	78.74

At the International Railway Congress, held at Milan, Italy, in 1887, Mr. Kowalski presented the following particulars:

There were 92.13 miles of metal track in service on December 31, 1886; this included 30.07 miles of the "Vantherin" ties, 1.24 miles of the Haarmann system (as a test), 27.03 miles with the company's type of ties, and 33.79 miles with the Vantherin and the company's ties mixed. The latter are straight, with riveted tie plates giving the inclination to the rails; the mixed plan was adopted to remedy the inconveniences of the old type of "Vantherin" ties with open ends, by replacing these ties at the joints with ties of the new system. Up to 1882 they were of iron, but since that time of mild steel. The joint ties are heavier than the intermediate ties; the first weigh 111.10 pounds, the latter 96.8 pounds; the fastening plates weigh 1.32 pounds per pair, the bolts .88 pound each, making a weight of 117.26 or 102.96 pounds per tie complete. The ties are placed on embankments and in cuttings, on curves and tangents, on grades and level line. The ballast is of fine sand and gravel, and the ground in some places is marshy. The traffic over the metal ties is very heavy; on some parts there are more than sixty trains per day, with speeds of 52.7 to 55.8 miles per hour. The train loads are about 700 or 800 tons, and the engines weigh 68 tons. The rails are of hard steel, weighing 77.65 pounds per yard. The experience dated from 1868, and the results were so satisfactory, especially as to the solidity of the track, even in case of accident, that the use of metal ties was being continued. At the prices of that time (1886) the cost per meter of track was as follows: On half-round oak ties treated with chloride of zinc, $1.79; on mild steel ties of the company's type, $2.28; the rails with splice bars and bolts are included at $1.09; a wooden tie, with four spikes, cost only 59.4 cents; a metal tie, with fastenings, costs about $1.04. The first "Vantherin" ties were too light and had been abandoned; the strengthened "Vantherin" ties dated from 1878–'79, and had necessitated 2 per cent. of renewals per year during the three years previous to 1887; of the company's ties laid in 1880, none had been renewed up to 1887. The track on metal ties is very elastic and very agreeable for passengers. The results were so satisfactory that from 1887 the company intended to lay 1,000 tons (about 22,000 ties) per year.

DUTCH-RHENISH RAILWAY.—Ties of the Vautherin type were used up to 1885. They were of wrought iron, 8.53 feet long, 4 inches wide on top, 9.2 inches wide at the bottom, and 2.4 inches deep; the bottom flanges were .8 inch wide; the thickness was .28 to .32 inch at the sides and .36 inch on top. The weight was 99 pounds. The tie was horizontal, closed at each end by an angle plate. A tie-plate was used to give the required inclination to the rail, and the fastenings consisted of bolted clamps on the Ruppel system (see "Germany: Prussian State Railways"). Being of wrought iron the bolt-holes were found to wear large. The following is Mr. Bricka's statement of the track for 1884:

	Miles.
Main lines	167.10
Local lines	3.10
Total track	339.14
Wooden ties	267.84
Metal longitudinals	6.82
Metal ties	64.48

DUTCH CENTRAL RAILWAY.—In Mr. Bricka's report to the minister of public works (France), in 1885, this road is mentioned as a line of minor importance. Since about 1878 experiments have been made with wrought-iron ties similar to those on the Main-Neckar Railway, in Germany, with fastenings similar to those used on the Left-Bank-of-the-Rhine Railway, in Germany. They gave good results and effected an economy in maintenance. The following is a statement of the track for 1884:

	Miles.
Main lines	62.62
Local lines	1.24
Total track	81.84
Wooden ties	35.96
Metal ties	45.88

TIES.

The Post Ties.—(See plates Nos. 8 and 9.)—These ties have been described in detail under the head of the Netherlands State Railways. Mr. Post's main improvement is in the variation of the thickness and in the methods of manufacture, and he has shown how this method might be applied to improve other forms of ties in use. While the wear of steel ties at the point of contact with the bolt may be very small, Mr. Post has considered it well to increase the thickness of the tie at this point; it adds little to the weight of the tie, but increases its life, and is especially adapted for light ties with a thin top-table. A middle rib on the underside of the table increases the thickness at the bolt-holes; this rib runs the whole length of the tie, being thickest at the rail seat and decreasing towards the middle and ends. With an extra thickness of .16 inch at the bolt-holes, the weight of the tie is only increased by 6.6 to 8.8 pounds, and it enables a reduction of 22 or 33 pounds to be made (without changing the thickness at the bolt-holes) in the exaggerated weight of some rolled steel ties of varying section, such as the two types of the Belgian State Railway, which weigh 165 pounds each, corresponding to 189¾ pounds of a tie of uniform section. The material used is soft or mild steel, necessarily of good quality in order to stand the process of manufacture and the tests. The specified tests require a piece of a tie to be flattened cold under a steam hammer, and the plate then bent to a curve of 3 inches radius without cracking. Another piece must have the sides pressed together till the tie is of ∩ section, with a top curve of .6 inch radius. The fastenings have proved efficient, so that direct contact between the rail and tie is not considered any objection; there is little if any more noise than with wooden ties; there is no rattling, and crystallization of the metal has not been found to occur. The effect of making the middle of the tie deeper and narrower is to give the tie a better hold on the ballast, to force the ballast to pack under the rail seat, and to increase the stiffness of the tie so that it will be strong enough should the ballasting give way. Ties of Type VI have been made for rack railways, the thickness being increased at the holes for the bolts which support the rack-rail chair at the middle of the tie in the same way as described for the ordinary bolt-holes.

The manufacturers have been required to guarantee to replace damaged ties during two years, but now this has been increased to five years. A tie of this type has been designed for the Indian gauge of 5 feet 6 inches. It is 8 feet 7⅜ inches long, horizontal at the middle, inclined 1 in 20 at the rail seats, and closed at the ends; at the rail seats it is 9¼ inches wide and 2¾ to 3½ inches deep; at the middle it is 4.4 inches wide and 5 inches deep. The thickness of the sides varies from .24 inch at the bottom to .31 inch at the upper part; the thickness of the top varies from .28 inch to .43 inch, the latter being at the rail seat. Weight, 125¼ pounds. Instead of bolt fastenings lugs are to be stamped up out of the tie and a steel key driven between the rail flange and the lug on one side; the system is the same as that now used with steel ties on the Indian State Railways and other lines, and is claimed to be cheaper and better than the bolt system used in Europe. A similar tie, but weighing only 116 pounds, has also been designed and is said to be as strong as the steel ties now used in India. In a proposal made by Mr. Post's English agent for a supply of ties for the Indian State Railways, he bid for the "Post" tie and for the type of tie specified by the engineer;

the price was slightly in favor of the former, owing to its reduced weight with equal strength. The price quoted to me in February, 1888, by this gentleman was about $25.62½ per ton at the port.

In September, 1887, there were in service in railways in Belgium, France, Holland, Germany, and Switzerland about 334,500 "Post" ties, or about 18,753½ tons. There were in course of manufacture 83,900 ties for standard gauge, weighing 4,363 tons; for a gauge of 3 feet 6 inches in Sumatra, 70,000 ties, weighing 3,040 tons; for rack railways, 20,000 ties, weighing 760 tons; an aggregate of 518,400 ties, or 26,916½ tons. In March, 1888, Mr. Post stated that there was a total of about 457,300 ties (about 23,800 tons) of types VI, VII, VIII, and IX then in the track in different parts of the world, and that about 272,700 more (about 12,700 tons), including the narrow gauge and rack railway at Sumatra (See "Asia") were ordered and being manufactured. This made a total of about 730,000 ties, or 36,500 tons. They were in use in Holland, Belgium, France, Germany, Switzerland, and Asia (colonies). About 50,000 ties have been introduced into the Argentine Republic. In January, 1890, Mr. Post stated that in addition to the ties in Holland, Belgium, France, Germany, and Switzerland, there were 200,000 in Sumatra, 50,000 in the Argentine Republic, and 71,000 were to be sent to the Transvaal (South Africa) in February. Within three months there would be, he stated, a million of these ties in service.

The following table, prepared by Mr. Bodmer, civil engineer, the London agent, shows the number of "Post" ties sold up to September 26, 1889. Bids had also been invited for 71,430 ties for the Dutch South African Railway. The contraction referred to is making the tie narrow and deep at the middle:

Where used.	Contraction.	Number.
Netherlands State railway	With	12, 732
Do	Without	47, 390
German State railways:		
Magdeburg	do	44, 200
Cologne	do	1, 700
Altona	do	3, 000
Strasburg	do	33, 000
Cockerill, Seraing, Belgium	do	200
Military railway, Schoneberg	With	5, 750
Do	Without	2, 300
German State railways:		
Frankfort	do	108, 492
Erfurt	do	61, 487
Friedrich Krupp, Essen, Germany	do	400
Pfalz railway, Germany	With	176, 000
Fortifications, Spandau	do	1, 050
Dutch Colonies, Sumatra	do	100, 000
Bavarian railway, Ritaikon-Ingolstadt	do	360
German State railways (Berlin)	do	2, 020
Jura, Bern, Luzern railway (Switzerland)	do	6, 000
Carlos Stegman, Carlsruhe, Germany (for the Argentine Republic)	do	50, 000
Total		656, 181
Manufactured in France and Belgium		200, 000
Total		856, 181

SUMMARY OF METAL TRACK FOR HOLLAND.

Railways.	Longitudinals.	Cross-ties.
Netherlands State (1888)		91. 00
Holland (estimated to 1889)	1. 24	120. 00
Dutch Rhenish (1885)	6. 82	64. 48
Dutch Central (1885)		45. 88
Total	8. 06	321. 36

BELGIUM.

GENERAL REMARKS.—In this country quite extensive experiments with metal track have been made on several lines, and the Government has conducted experiments on the State railways since 1846. In 1885 and 1886 the subject of the use of metal ties was warmly discussed in the Chamber of Representatives, the principal object being to forward the interests of the iron industry; the minister of railways then secured an appropriation of $180,000 for the purpose of carrying on further experiments on the State railways. In March, 1889, at a meeting of the chamber, the minister stated that the results had not been satisfactory. He had hoped that if the tests were successful the authorities would have been able to adopt metal track on a part of their system, and thus render a great aid to the national industry by advancing the condition of the iron trade. At this meeting there was a rather sharp discussion on this point, several of the members being in favor of more extensive tests and wishing tests made of the "Z-iron" tie [described later on]. The minister stated then that three types of metal ties had been tried; of these one had failed, but the inventor claimed that the failure was due to a defect in the quality of the material, and he was granted a further trial; the other two systems had not been long enough in service to enable a definite opinion to be given. He was opposed to increasing the number of types to be experimented with. The Government has been asked to have these "Z-iron" ties tried on the State railways, but the minister of railways declined on the ground that the Government preferred to await the results of the trials being made on the State and concessionary lines before proceeding with new trials or adopting new types. Mr. Bricka, in his report to the minister of public works (France) in 1885, stated that Belgium was the only country in which after a trial on a large scale metal track had been at one time almost entirely abandoned. He attributed this to the fact that the trials to which he referred, covering a length of 23.56 miles, were made by order of the Government on account of the agitation raised by the metal industries about 1877. It was proposed to lay about 93 miles at once. The ties were of the original "Vautherin" type; they were not of a good section and were of very poor material; proving unsatisfactory they were taken up and no attempts were made to improve upon the system. A similar agitation was raised in 1884, and a commission was sent to investigate the progress being made in Germany, with the result that the Belgian engineers began to have a better opinion of metal track. Since then the Government has ordered trials to be made with different types of track, and these trials are still being carried on.

Wooden ties.—The West Flanders Railway reported in August, 1888, that metal ties have not been employed, as oak ties 10.4 inches by 5.2 inches can be procured for 70 cents each.

Belgian State Railways.—Experiments with various forms of metal track have been made on the State railways since 1846 and are still in progress. Up to 1885 only unsatisfactory results had been obtained; but this was attributed to bad or defective designs or material, and did not cause the abandonment of the trials.

In March, 1886, Mr. Flamache, engineer of the State railways, presented a paper at a meeting of the Belgian Society of Engineers, on "The History of Metal Railway Tracks," to which was appended a note by Mr. Mussely, an engineer of the same roads, detailing the trials made since 1846. These trials were briefly as follows: In 1846 there were four systems in use on the line between Brussels and Antwerp: (1) the Poncelet system of semi-circular plates of cast-iron, with rolled-iron tie-bars; (2) the Poncelet system with square plates; (3) the Gobert system of two cast-iron plates with an old rail reversed, this rail having a notch which formed a chair; (4) the Marchal system of rolled plates, with ordinary chairs secured by bolts and nuts. In 1851 the administration put in 5,000 ties of the Greaves and Barlow system, similar to the Poncelet system. In 1868, 7,804 "Vautherin" ties were laid. About 1869, 500 tons of the Legrand-Salkin system were laid. Between 1872 and 1879 several systems were examined, but none were considered worthy of trial. In 1878–1879 there were laid 74.56 miles of single track with the Hilf longitudinals (See "Germany") and 94,035 miles of single track, similar to the Rhenish Railway type (See "Germany"). In March, 1879, 2,000 of the Desoignies cross-ties were laid. In 1879 the Serres and Battig system of longitudinals was tried. In 1881,500 Helson ties were laid. The Hilf longitudinals were similar to those on the Alsace-Lorraine Railway, Germany; but there was much trouble from breakages, owing to the bad quality ot the metal, and at the end of four years all of the track was taken out. With the Serres and Battig system there were many breakages, owing, the inventors claimed, to the quality of the material; these were soon abandoned. The "Vautherin" ties, laid in 1878, were 7.87 feet long, 4 inches wide on top, 9.52 inches wide at the bottom, 2.4 inches deep; the top table .36-inch thick; the bottom flanges .96 inch wide and .32 inch thick. The ties were curved longitudinally, to give the rail its inward inclination, and near each end a piece of angle-iron was riveted with the vertical leg inside the tie. The fastenings were on the Ruppel plan (See "Germany—Left Bank of the Rhine Railway"), consisting of bolted clamps with lugs fitting into holes in the tie; at the joint ties the clamps extended over the whole width of the rail-flanges. The weight was 105.65 pounds. The 2,000 Desoignies ties were laid on the line from Brussels to Ghent; they were of approximately rectangular section, weighing 88 pounds; the fastenings consisted of a riveted clamp on one side, and a bolted clamp on the other side, of the rail. Owing to the poor quality of the iron, breakages occurred with both these types, and the holes were enlarged, while, owing to their being curved and laid in broken-stone ballast, the track was not stable. These were only in service for about two years.

In December, 1885, it was decided to try 35,000 ties of the "Post" type, but heavier than those on the Netherlands State Railways; 35,000 ties of the Braet plan, being a modification of the "Post" type; and 5,000 ties of the Bernard type.

The first were of the old form, 8.2 feet long, 10 inches wide, 2.84 to 3.6 inches deep, .48 inch thick in the middle, and .64 inch thick at the rail-seat; the fastenings consisted of bolted clamps with spring washer nut-locks. There were twelve ties to a rail length of 29.52 feet, and the rails were laid with suspended joints. The weight was 165 pounds per tie. Mr. Bricka considered this too heavy, and thought that a thickness of .32 inch to .48 inch would be sufficient. The "Braet" ties were designed or adapted by Mr. Braet, engineer of the Belgian State railways; they are 8.2 feet long, 10.8 inches wide at the bottom, 3.8 inches deep at the middle, and 4.4 inches at the rail-seats; the thickness is .36 inch at the middle and .52 inch at the rail-seats; the weight is 165 pounds. With both these types the Ruppel plan of bolted clamp-fastenings is used. The Bernard tie is composed of two channel-irons 7.54 feet long, 4.8 inches high, and 2.24 inches wide over the flanges; the thickness is .24 inch. These are placed back to back, 7.32 inches apart, and at each end is a flat base-plate 16 inches wide and 36 inches long, fastened to the bottom flange of each channel-iron by four rivets .80 inch diameter, and turned up to close the end of the tie. At each end of the top of the tie is a grooved tie-plate 7.96 inches wide and 13.2 inches long under the rail, resting on the top of the upper flanges of the channel-irons; the plate gives the usual inward inclination to the rail. Hook-headed bolts pass through the upper flanges of the channel-irons and through the tie-plates, the rails being fastened by large washers or clamps, with a recess in the top to receive a coiled-spring nut-lock. The tie is filled with and buried in the ballast, to increase its weight and the stability of the track. The weight, complete, is 231 pounds, and there are eight ties to a rail length of 22.96 feet. It was said during the discussion in the chamber that they had not given satisfactory results (see "The Bernard Tie"). The "Post" ties were made at the Louviere works, and cost $24.09 per ton; the "Braet" ties were made at the Cockerill works, and cost $23.80 per ton; the "Bernard" ties were made at the Couillet works, and cost $29.90 per ton.

The following particulars are taken from a special report sent to me in May 1888, in regard to the track laid with the "Bernard" ties. There were about 3½ miles (18,450 feet) of line laid with 5,000 of these ties; 4,000 were on grades of 0.16 per cent. and 1,000 on level track. The first were laid in 1884, the remainder in June, 1886. Mr. Mathieu was the engineer. The weight of the tie is given as 215.6 pounds. The cost is $2.90 per tie at the works, the durability and the cost of maintenance are not yet determined. The metal is not painted or treated in any way. Passenger and freight traffic is hauled over the line; the engines weigh from 35 to 75 tons, including tenders, and the cars weigh empty 4 to 9 tons. The rails are flange section, 76.5 pounds per yard; the joints are suspended and fastened by splice-bars. There are 8 ties per rail length of 29.52 feet. The ballast is of broken stone; it is 20 inches deep in the middle, level with the top of the ties between the rails, and level with the rail-heads between the tracks and outside. The line is of standard gauge and the width of road-bed is as follows: 6.56 feet center to center of inner rails of double track, 4.92 feet center to center of rails of each track, 3.28 feet from center of outer rails to edge of ballast, 30 inches width of ballast slope. The reason for adopting metal ties was to obtain a solidity, a bearing-surface, and a weight which would increase the durability and diminish the expense of maintenance. The results have been very satisfactory; the track is solid, the fastenings hold well and give no trouble. No breakages had occurred and there was no trouble with maintenance. The ties present the advantage that on account of the extra length of bearing-surface they can be considered as two ties spliced together and the number can be reduced 33 per cent. below the ordinary number of ties. Their bearing in the ballast and their weight are very great, giving them exceptional stability. The climate is moist and variable, but no special observation has been made of its effect upon the ties.

The Cockerill tie.—A tie of the "Post" type, of which the Cockerill works sent particulars in February, 1888, was 8.2 feet long, 9.6 inches wide inside at the bottom, 10.8 inches wide over the ribs. The top was horizontal except at the rail seats, and the bottom was horizontal throughout. The ends were closed and bent below the level of the bottom of the tie, being 6 inches deep. Weight, 164.56 pounds. At the middle it was 3.64 inches deep with a top table .36 inch thick. At the outer part of the rail seat it was 4.4 inches deep with a thickness of .52 inch, and at the inside part it was 3.8 inches deep with the same thickness of the top table. The thickness of the sides was from .30 inch at the bottom to .36 and .46 inch at the top. The fastening bolts were 3.44 inches long under the head, .84 inch diameter, with ⊥ heads and hexagon nuts. The clamps were 2.28 inches by 2.60 inches, with a bolt hole .88 inch diameter; a lug at the outer side made the depth over all 1.80 inches, and this lug fitted into the oblong bolt hole (1.6 by .92 inch) in the tie. Spring washers for nut-locks are used. The rail joints were spliced with angle bars having a rib on the under side of the edge of the flange. The bars were 27.20 inches long, with four bolt holes, the inner ones 6 inches apart center to center, and the outer ones 4 inches. For a rail length of 29.52 feet there were twelve ties, spaced 22 inches apart center to center at the joints, 25 inches apart next to the joints, and intermediate ties 32 inches apart. Other ties of this type were 8.2 feet long, 8.88 inches wide inside, 10 inches wide over the ribs. The depth over all was 2.84 inches at the middle, where .48 inch thick, and 3 inches where .64 inch thick. At the rail seat the thickness was .64 inch and the depth 3.6 inches. The width of the top table was 5.04 inches, except at the rail seat, where it is 4.4 inches, and just outside it narrows to 3.78 inches. These ties are not narrow-waisted at the middle, but are of uniform section and thickness between the rail seats. The adjustment of gauge is effected by the use of clamps with lugs of different width, instead of by eccentric necks on the bolts. The more recent form of track has rails weighing 76.5 pounds per yard, with joints spliced by bars 31.84 inches long and four bolts, The joint ties are spaced 24.24 inches center to center.

From 1885 to May, 1888, 2,625 tons of the "Post" type of tie had been manufactured for these lines by the Angleur works. They were of Thomas-Gilchrist steel, not tarred or treated; they weighed 110 to 165 pounds each, and cost $22 to $25 per ton. Most of the ties of this type were considerably heavier than those used on the Netherlands State railways (Holland). Continued experience on these latter lines has shown the weight of 117.7 pounds to be sufficient in every way, and the inventor considers, as does Mr. Bricka, that the extra weight is quite unnecessary, involving extra cost, and only resulting in putting useless and dead metal into the track.

The Belgian State railways system comprises 1,990 miles, and on January, 1888, there were 219,485 metal ties in service.

GREAT CENTRAL RAILWAY—Different forms of metal track have been tried. Among them was the Serres and Battig system of longitudinals (See "Austria"), but there were many breakages and the trial was not successful. In 1873 the superintendent of permanent way reported that he was fully satisfied with the experience so far obtained with metal ties. He was unable to employ them further at the time in consequence of the extraordinary advance that had taken place in the price of iron. The company's report for 1887 stated that the favorable results during 1886 had been still more marked during 1887. In the latter year 6,000 additional metal ties were substituted for wooden ties. Satisfactory results are said to have been obtained with a "Z-iron" tie weighing 149.6 pounds and costing not more than $1.80 each; these were laid about 1887.

Since 1886 there have been in service 11,000 iron ties of two types, manufactured by Caramin & Co., of Thy-le-Chateau (see Plate No. 11), and they are giving very good results as to security and economy in maintenance, according to a statement sent to me by the engineer-in-chief in October, 1889. He stated that so far not a single one of these ties had been taken out of service, while on the state railways, where steel ties are used, quite a number had to be taken out owing to breakage. This unfavorable result he attributed to the alteration in the metal produced by the punching of the holes for the bolts. With steel special precautions must be observed in the manufacture, while with iron there is less need of such care. He does not, however, proscribe the use of steel for ties, but thinks much progress is still to be made in metallurgy before this material will be definitely successful for such purposes.

The ties now used weigh, complete, about 154 pounds; they are 8.52 feet long for standard-gauge track. This weight is sufficient for a moderate traffic with an average speed of 37.2 miles per hour for passenger trains, but he considers that the weight should be increased to 176 or even 198 pounds for tracks with very heavy traffic. Various kinds of ballast have been used with these ties; ashes mixed with earth (a very inferior quality of ballast), river gravel and broken stone; good results have been obtained with all these materials. The gravel should be slightly earthy, so as to form a solid core under the tie. This railway has a length of 365.18 miles.

These ties are of semi-cylindrical section, with horizontal flanges on the lower edges and having a flat top table; the horizontal flanges are cut away at the middle of the tie. They are 8.52 feet long, 3 inches deep, 6.4 inches wide inside at the bottom and 9 inches wide over the flanges; the upper face of the top is flat for a width of 3 inches. The flanges are .36 inch thick; the sides are .36 inch at the bottom and .40 inch at the top, and the top table is .52 inch thick. Inside the tie, under each rail, is an iron plate 10.8 inches long and about .75 inch thick, fastened by two rivets passing through the top of the tie. Each rail rests on a grooved tie-plate, giving the rail the usual inclination, and having a channel for the rail flange and a rib along each side. Short screws, about 3¾ inches long over all, pass through the tie-plate and tie and are tapped into the iron plate riveted inside; these screws have wide round heads, which bear on the flange of the rail and the rib of the tie-plate, and have a square projection on top for the track-wrench. The older ties of this form weighed 149.38 pounds complete; but the newer ones, adopted in 1887, weigh 152 pounds, made up as follows: Tie, 133.30 pounds; tie-plates, 5.10 pounds; riveted plates, 9.06 pounds; rivets, 1.63 pounds; screws, 2.91 pounds.

The other type of tie, adopted in 1886, was of similar section; but inside, under each rail, was an oak block 9.3 inches long; this was held in place by an iron plate 9.8 inches long, riveted to the tie by two rivets to each flange; the plate was about .27 inch thick, with a rib in the middle about 1.15 inches wide, making the thickness at that part about .56 inch. The rail rested on a tie-plate having a rib on each side, but no channel for the rail flange. The fastenings consisted of screws similar to those described above, but 6.12 inches long over all, passing through the wooden block and the thick part of the bottom plate. The weight of each tie, complete, was as follows: Tie, 130.64 pounds; tie-plates, 4.73 pounds; riveted plates, 17.20 pounds; screws, 3.96 pounds; oak blocks, 4.77 pounds; total, 161.30 pounds.

At the International Railway Congress, held at Milan, Italy, in 1887, Mr. Kowalski presented the following particulars respecting these ties:

Five thousand were laid in 1886 and 5,000 were to be laid in 1887; they were placed under unfavorable conditions and in ground imperfectly drained; they were on embankments and in cuts on tangents and curves of 1,640 feet, 1,968 feet, and 2,624 feet radius, and on a maximum grade of 3.5 per cent. During the first year the traffic consisted of 1,498 passenger trains and 2,920 freight trains, a total weight of 1,068,258 tons. The speed of the former is 37.2 miles per hour and that of the latter 15.5 miles per hour. The passenger engines weigh 31 tons, and the freight engines 52 tons. The rails are of flange section, weighing 74.35 pounds per yard. The ballast is of ashes and quarry gravel. The track keeps in good condition and the fastenings keep tight. The price of the iron tie is double that of the wooden tie. The work of maintenance during the first year of service was less than that of wooden ties. The arrangement of fastening with screws and an iron plate was being adopted in place of the wooden block.

NORTHERN RAILWAY.—On the Belgian lines of the Northern Railway of France, the "Severac" tie has been used. In 1885 there were 1,500 of these ties in the track, 750 at Engis, near Liege, and 750 near Charleroy. Since they had been laid 6,000 trains had passed over them, and no creeping of the rails or displacement of the keys which fasten the rails had been observed. At a meeting of the Belgian Society of Engineers in March, 1886, it was stated that 1,500 of these ties had been in service for nine months under a traffic of sixty-four trains per day, and were in as good condition as when laid, while no difference could be noticed between the noise when passing over these ties or wooden ties. They were manufactured by the Angleur Works (See "the Severac ties"). The following particulars are from a statement received in May, 1888, in regard to the "Severac" ties: In June, 1885, they were laid on 1,968 feet of single track on the line from Namur to Liege; and in July, 1885, on 1,968 feet of single track on the line from Erquelinnes to Charleroy. On the former section there were curves of 4,920 feet radius, and grades of 3.8 per cent.; on the latter section there were curves of 1,640 feet radius, and grades of 1.46 per cent. Mr. Bernard was the engineer of the line to Namur. The locomotives weigh about 38 to 69 tons in working order, including the tender; the cars weigh 3.6 to 8 tons empty. The traffic is passenger and freight. The tie is an **I**-beam, 8.2 feet long, 4.8 inches high, 3.2 inches wide over the flanges, .32 inch thick; on the bottom is a plate 9.6 inches wide and .32 inch thick, secured by eighteen rivets; it runs the whole length of the tie and is turned up at the ends. A chair for the rail is riveted to the top at each end of the tie. The weight of the tie complete is 204.6 pounds. The ties are made of iron at the Angleur Works; they are not treated in any way, and cost the railway company $1.08 each, but the net cost at the works was higher than this, according to the statement of the inventor. The cost of maintenance had not been defined, but was very low. The joint ties were spaced 24 inches apart, center to center, and the intermediate ties 34 inches. The ballast is of ashes; it is 20 inches deep in the middle, level with the rails between and outside of the tracks, and level with the tops of the ties between the rails. The dimensions of the road-bed are as follows: 6.56 feet between tracks (center to center of rails), 4.92 feet center to center of the rails of each track, 3.28 feet from center of outer rails to top of ballast slope, 30 inches width of ballast slope. The rails are of flange section, weighing 60.36 pounds per yard; the joints are suspended, and are spliced in the usual way. The reason for using metal ties was to compare the cost of their maintenance with that of the track on wooden ties. The results were satisfactory; there was no trouble with maintenance, and the only trouble with the rail fastening (a taper key driven between the rail flange and a lug on the tie plate) was that before driving the keys to a tight bearing it was necessary to dress the track in line and surface, as after the keys have been finally driven this dressing is impossible on account of the extreme stiffness and rigidity of the track. The only breakages were in the chairs which appeared to be rather weak; no accidents were caused by these breakages. The ties appeared to behave much the same as wooden ties; they are well made, but as regards bearing they do not present more advantages than wooden ties, which would have a width of 9.6 inches. The climate is moist and variable, but no particular observations have been made of its effect on the ties. Oak ties cost $1.17 each, including the rail fastenings, and have an average life of fifteen years. Creosoted beech ties cost $1.09 each, including rail fastenings, and have an average life of twenty years.

LIEGE AND LUXEMBOURG RAILWAY.—The Serres and Battig system of iron longitudinals (See "Austria") has been tried, but with unsatisfactory results owing to numerous breakages. The "Coblyn" type of cross-ties has also been used. The principal trials have been with the "Post" type of steel cross-tie, with very good results, as noted under "Holland," Netherlands State Railway.

LIEGE AND SERAING RAILWAY.—The Society of Economic Railways (Liege to Seraing and extensions) has, after making experiments, adopted the "Coblyn" type of steel ties to replace oak ties. In the company's report presented at a meeting in May, 1888, it was stated that renewals with these ties would be carried on as needed, and by small sections.

LOCAL RAILWAYS.—A special statement received in May, 1888, shows that the Local Railways Company laid in December, 1887, 500 iron ties of the "Bernard" type, covering 2,437 feet on the line from Jedoigne. They were on tangents and curves of large radius, also on grades and curves, to 98.4 feet radius. Mr. Dartevelde was the engineer. The ties and fastenings were of steel, but the chairs were of iron. The weight per tie was 132 pounds, and there were 6 ties to a rail length of 29.52 feet. The cost was $2.10 each at the works. The rails were of flange section, 6.4 inches high, weighing 60.36 pounds per yard; the joints were suspended. The results, etc., are the same as given in the statement relating to the Belgian state railways. Trials have also been made with the "Coblyn" type of steel ties.

For the Charleroy suburban lines the company has adopted the "**Z**-irŏn" tie. These lines are 9.3 miles long, one meter gauge, with maximum grades of 6 per cent. and curves of 82 feet radius. There are three lines; on two of them the traffic consists of thirty trains per day, and on the third line fifty-four trains. The lines were opened in 1887, and the track has given good results from the beginning, especially in regard to its freedom from noise; there were 12,829 ties in service. The lines follow the country roads, and the track is in some places in the paved streets, and in other places on waste ground along the side of the highway. The ties weigh 114.4 pounds each, including fastenings, and cost $1.30 each. The passage of trains is as easy and quiet as on track with wooden ties; the crossings are laid with wooden ties and no difference is noticed when the trains pass from track with metal ties to track with wooden ties, or *vice versa.* This is claimed to be due to the rigid fastening of the rails by a taper key.

The following is an abstract of a report made to the company in October, 1888, by Mr. F. Grumieaux, engineer and superintendent of the Charleroy lines:

> The lines are of very irregular profile; of the 9.3 miles total length, 6.2 miles present grades of 3 and even 6 per cent. The rails are 29.52 feet long; those laid in the streets weigh 60.3 pounds per yard and have eight ties to a rail length; those laid at the side of the road weigh 43.2 pounds per yard and have ten ties to a rail length. The passage of trains is as smooth and easy as on track with wooden ties, as can be noted at crossings where wooden ties are used. The taper keys first used were too small; on the Lodelinsart line, where there is a grade nearly 1.24 miles long, varying from 3.5 to 6 per cent., down which the engines run with the brakes partly applied, there was considerable creeping of the rails, the ends of the rail touching one another and the ties being shifted laterally so that the tangent became a series of bends. This part of the track was relaid in June, 1888, and stronger keys were used, after which there was neither creeping nor displacement of the track. The ties taken out had a thin coat of rust, but the experience was then too short to allow of any opinion to be formed as to the ultimate effect on the ties. Some Belgian engineers have affirmed that metal ties can only be used with gravel or broken stone ballast, as ashes will destroy them by corrosion, owing to the sulphurous matter contained in this material. These lines, however, are ballasted entirely with ashes, and the future will show whether the opinions of these engineers are well founded. No figures could be given as to the cost of maintenance and repairs, and in fact German and Dutch engineers are of opinion that it is not until the third year of service that the good results of the use of metal ties become apparent.

The Severac Ties (See plate No. 10).—The "Severac" tie consists of an I-beam with a broad plate riveted to the bottom; this plate extends the whole length of the tie, and is turned up at the ends. The size of the plate on plan is exactly that of an ordinary wooden tie and the height and width of the closed end are the same as those of a wooden tie, so that the volume of the ballast resting on the bottom plate is practically equal to the volume of a wooden tie. By this means the tie itself may be comparatively light for handling, say about 198 pounds, and very heavy when in place in the track, being more firm or stable than wooden ties. To the top table of the I-beam are riveted two rail chairs, giving the rails an inward inclination. There are two projecting lugs on each chair: the outer one holds the outer flange of the rail, while the inner one has a taper steel key driven between it and the rail flange.

There are various modified forms of these ties. They may have a plate riveted on the top as well as on the bottom; or they may be rolled with a narrow top flange and a wide bottom flange, so as to dispense with the riveted plate, the bottom flanges being cut through at the corners and bent up to form a closed end. They may also be of tee-section (T or ⊥), with the horizontal flanges bent down or up, as the case may be, to close the ends. This form may be used for narrow-gauge lines, the horizontal flanges being bent down or up and then horizontally, so as to form a top table at the ends and a bottom table at the middle, or *vice versa;* this is advantageous for lines where it is desirable to economize in the width of the ballast, as the resistance to lateral motion is then at some distance from the ends of the tie. (This is one of the special features claimed for the Standard steel tie, now being tried in the United States.) Another form is of ⊥-section, with a piece of angle-iron riveted to each side of the top of the web, under each rail, forming a rail seat. Another form is of similar section, but has a saddle piece of Λ-shape at each rail; the flat top rests on top of the web of the tie and forms a rail seat, while the horizontal flanges are riveted to the bottom flanges of the tie. The fastening intended to be used was a bed-plate of mild steel riveted to the tie; there were two lugs, the outer one holding the outer flange of the rail and the inner one being bent down to hold the inner side of the flange, or bent back when a rail or tie was to be removed. This would require a very soft metal to stand this bending and rebending without cracking, and steel made by the Gilchrist process was considered the best for this purpose. The fastenings by means of lugs and a key have, however, given excellent results. While this tie weighs, in position in the ballast, about 330 pounds (metal and stone), an ordinary wooden tie only weighs about 154 pounds.

The inventor had the following objects in view in designing this form of tie: (1) the suppression of movable fastenings, so that the tie could be made complete at the works, the track men only requiring a hammer for the bent lug; (2) the same base and the same resistance to longitudinal and transverse motion as a wooden tie; (3) easy ballasting; (4) the maintenance of the gauge and the inclination of the rails; (5) easy placing and removing; (6) ease of manufacture. In regard to this last point, however, it may be noted that the ties in use, with eighteen rivets each, represent a good deal of shop-work.

These ties have been tried on the Belgian lines of the Northern Railway of France.

The Bernard Ties (See plate No. 10.)—Mr. Bernard, engineer of the Belgian division of the Northern Railway of France, has invented a cross-tie consisting of two channel-irons placed back to back, and with a broad bed-plate riveted to the bottom at each end, each plate having eight rivets, and the end of the plate being turned up to make a closed tie. Each rail rests on a chair secured to the top of the channels by bolts, the ⊥ heads of which are on the under side of the top flanges of the channels. A special form of nut is used, having part of its lower face plain and part indented; the plain part bears on a washer which is large enough to leave a space between it and the bolt. In this space is a spring nut-lock of one spiral; the lower part of the spring has a lug which fits into a hole in the rail clamp, and the upper part has a tooth engaging with the teeth on the lower face of the nut and so preventing it from working loose. The tie may be made with two **Z**-irons instead of channel-irons, the lower flanges being inward. They can also be adapted for double-headed rails by using the regular chairs for this form of rail instead of the flat chair for flange rails.

In a pamphlet upon his patent tie, Mr. Bernard says:

"The tie may be considered as formed of two ties united; it presents two bearing points for the rail, so that the distance between these ties is gained in the general spacing of the ties and their number can be reduced 33 per cent. The distance between the two bolts on each side of the rail is 12.16 inches. For eight ties to a rail length of 29.52 feet, the joints are suspended, and the arrangement is 11.2 inches center to center of bolts of joint-ties, and 34.2 inches between the adjacent bolts of intermediate ties, except that the distance between the two middle ties is 35.12 inches. For six ties to a rail-length of 29.52 feet, the joints are supported and the arrangement is 41.68 inches between the bolts of the joint and shoulder ties, and 50.92 inches between those of the intermediate ties. The weight is from 242 to 305.8 pounds, but as each tie of this type is equivalent to one and a half ordinary ties, the comparative weight would be about 160 and 203 pounds respectively. For the spacing of six ties to a rail-length of 29.52 feet, Mr. Bernard suggests a rail about 6.4 inches high, 4.2 wide over the flange, 2.48 wide at the head, and weighing about 86 pounds per yard. The sixteen rivets per tie represent a good deal of shop-work, as with the 'Severac' tie."

These ties have been tried on the Belgian State railways and the lines of the local railways company.

The Coblyn Ties (See plate No. 10).—These are steel cross-ties of approximately **T**-section, but with a deep groove along the middle of the top table; the edges of the top table are turned down slightly and the ends are closed. For standard gauge lines they are about 7.8 feet long, 9.6 inches wide over all, 3.64 inches deep in the middle, and 1.04 inches at the sides, .32 inch thick on top, and weighing about 112.2 pounds. The cost, with fastenings, complete for rails weighing about 72.33 pounds per yard is about $1.89 per tie. For meter-gauge lines they are about 5.9 feet long, 8 inches wide, 3.5 inches deep in the middle, and .96 inch deep at the sides, .32 inch thick on top, and weighing about 61.6 pounds. The cost, with fastenings, complete for rails weighing about 42.25 pounds per yard is about $1.26 per tie. A special form of fastening is designed to be used with the heavier flange rails. The rail rests on a chair riveted to the tie; the inner side of the flange is held by a lug projecting 1.6 inches over it; on the outer side is a high jaw inclined toward the rail; over this fits a loose cap, with its inner face also inclined, and having a vertical groove; a taper wooden key is driven between the side of the cap and the web of the rail and bears tightly against the under side of the rail head; the wood swells into the groove in the cap so that the key can not work loose. The several parts of the fastening are stamped at the works. This fastening may be used for wooden ties, and it is claimed that the use of the tie plate will increase the durability of wooden ties and enable soft woods to be used.

These ties have been tried on the Liege and Luxembourg Railway, and adopted on the Liege and Seraing Railway. The riding over metal ties with the fastening described is said to be as quiet as, if not quieter than, over wooden ties with ordinary clamp or spike fastenings holding the rail by the flange; this is attributed to the holding of the rail by the web and head with an elastic body, which absorbs the vibrations. These ties give a good bearing for the rail, make a stable track, are easily ballasted, and may be used with broken stone or slag ballast.

*The **Z**-Iron Ties* (See plate No. 10).—These ties are composed of two rolled beams of **Z**-section, with vertical web, placed side by side with the lower flanges inward. At each end is placed a cast-iron rail chair with wings projecting down into the tie between the two beams; three rivets passing through each chair and the webs of the beams hold the pieces firmly together. The **Z**-irons present a great resistance to vertical bending motion, and the tie is very strong. The weight, including fastenings, for ordinary track, is about 195.8 pounds, and for rails weighing 100 pounds per yard about 209 pounds. The Z-irons for these heavy ties are about 2.6 inches wide, 4.4 inches deep, and .28 inch thick. The rails are of flange section, and are given the usual inclination by the seat of the chair; there is a lug on each side of the plate; the outer lug fits over the outer side of the rail flange, and a taper key is driven horizontally between the inner lug and inner side of the rail flange; to prevent the key from slacking back the end is split, and may be opened with a chisel when driven home, and a small wooden or metal wedge may be driven into the split end. This makes a very tight and secure fastening; the rail is fixed as in a vise; the surfaces in contact being extended, there is no wear or play, and consequently no vibration or rattling. It is estimated that the proposed ties, weighing 209 pounds, would cost $2.45 each, or $4,740.75 per mile with 1,935 ties per mile; white oak ties would cost, with plates and fastenings, $1.90 each, or about $4,907 per mile with 2,580 ties per mile. The reduced annual cost for maintenance is a special advantage. It is calculated that the annual cost per yard for maintenance would be with the metal ties 21.7 cents for ten years, 17.15 cents for fifteen years, or 12.21 cents for thirty years. With wooden ties 8 feet 2 inches long, 12 by 6 inches section, it would be 30.62 cents for ten years, and 22.92 cents for fifteen years. The track can be more readily and quickly laid than with rails spiked or clamped to wooden ties. The weight of the tie in the track is increased to about 396 pounds by the ballast within it, and it is very easily tamped and ballasted. These ties are to be given trials in various countries. The Congo Railway Company (in the interest of the Belgian Government) has ordered these ties for 270 miles of road, from Matade to Stanley Pool. The chief engineer of the Ottoman Railway, of Turkey (owned by an English company), has recently been in Belgium with a view to replacing the wooden ties with "Z" ties. The following railways also intend to experiment with them: Loando and Ambaca, in the Portuguese territory of the Congo; Portuguese State railways; Minho and Douro Railway, Portugal; South and Southeastern Railway, Portugal; State railways, France; Egyptian railways; Bone and Guelma Railway, Algeria.

SUMMARY OF METAL TRACK FOR BELGIUM.

Railway.	Metal cross-ties, (about).
	Miles.
State	100.00
Great Central	5.00
Northern	.75
Local	9.75
Total	115.50

GERMANY.

General Remarks.—Germany has an extensive system of railways, most of which are State railways. The principal system of the German Empire is that of the Prussian State railways, which are owned and operated by the Prussian Government; the system is divided into divisions corresponding with the several provinces of the Prussian Kingdom. The railways of the other States of the empire, not belonging to Prussia, are owned by the governments of these States as a rule. There are also several private railways, some of which are under government control. The lines are principally of standard gauge, 4 feet 8½ inches.

In this country very extensive experiments with metal track have been made, the experiments extending over a number of years and including trials of various types of track. The experience has been in general in favor of the metal track, and has led to its being adopted in some cases. The first experiments were made in 1862, and in 1880–'81 there were 2,875.5 miles laid with metal track, equal to 8.1 per cent. of the total mileage then in operation. In January, 1885, there were 3,234.54 miles laid with metal cross-ties, and 3,145.26 miles with metal longitudinals, a total of 6,379.80 miles of metal track, representing 16.52 per cent. of the total length of single track, which was then 38,608 miles. The following table, showing the growth of different classes of track on German railways, from 1878 to 1884, is from the report of Mr. Bricka to the minister of public works (France), and to it I have added the official figures for 1888:

Mileage of German railways, 1878–1884.

Year.	Main lines.	Local lines.	Total track.	Wooden ties.	Metal longitudinals.	Metal ties.	Stone, blocks, etc.
1878	18, 645. 88	833. 28	33, 343. 60	32, 008. 74	902. 10	175. 46	257. 30
1879	19, 041. 44	1, 582. 86	34, 904. 76	32, 621. 30	1, 574. 18	489. 18	220. 10
1880	18, 886. 44	1, 988. 96	35, 522. 90	32, 399. 34	1, 980. 28	828. 32	314. 96
1881	18, 978. 82	2, 165. 04	36, 061. 68	32, 150. 72	2, 359. 72	1, 240. 00	311. 24
1882	19, 001. 76	2, 582. 92	36, 906. 12	32, 088. 72	2, 604. 00	1, 905. 26	308. 14
1883	18, 982. 54	3, 059. 70	37, 697. 86	32, 008. 74	2, 892. 92	2, 485. 58	310. 62
1884	18, 931. 70	3, 642. 50	38, 608. 02	31, 914 50	3, 145, 26	3, 234. 54	313. 72
1888	19, 169. 16	5, 107. 56	41, 290. 76	32, 147. 62	3, 562. 52	5, 224. 12	356. 50

During the past decade there has been considerable activity in the introduction of metal track, and the results have been in general thoroughly satisfactory. This experience is of more practical value than that of the earlier experiments, as the earlier forms of track were naturally deficient in many ways, while the more recent forms have been designed in accordance with the teachings of experience and have been in service under modern conditions of traffic. Both longitudinals and cross-ties have been tried on an extensive scale, but the former are not being used to any extent for new work, while large quantities of cross-ties are being introduced continually. It is stated on authority that on new lines and on such old lines as are to be thoroughly repaired, the Hilf system of longitudinals is not to be used any more, and the Haarmann system of longitudinals only to a limited extent. The reasons given are that the maintenance is difficult and the construction and drainage of the road-bed especially difficult. As regards the life of the ties, that is a point as yet undetermined; the earlier forms of ties were too weak for modern conditions of traffic, and those fitted for such conditions have only been in service for from five to ten years. On the Elberfeld division of the Prussian State railways (Westphalia), it is considered that metal ties will not have a longer life than wooden ties (fifteen years maximum); but in view of the experience with the earlier ties and of the durability of steel rails, etc., this estimate can hardly be considered as correct. Mr. Gustav Meyer, chief engineer of the Prussian State railways, is of opinion that the life of metal cross-ties of modern design may be estimated as at least double that of the best wooden ties, or thirty to forty years. Metal ties have been definitely adopted on some lines.

Wooden ties are still used to a very great extent, partly owing to the policy of the government to foster and develop the forests and encourage the forest industries, and partly on account of their smaller first cost. The native forests can not supply nearly enough timber to meet the demands, and large quantities of wooden ties are imported annually. The appropriations for railways in 1888 included about $2,500,000 for wooden ties and only $1,000,000 for metal ties, and it was estimated that the importation of wooden ties amounted then to $450,000. This has roused the iron and steel manufacturers, who have called the attention of the government to the fact that metal ties are a success in point of efficiency and economy, and they have petitioned the government to provide for a more rapid introduction of such metal track in the interests of the iron industries. Large quantities of metal ties are made for export; according to a report by Mr. Tanner, United States consul at Chemnitz, Germany exported 26,991 tons of steel ties in 1885 as compared with 17,000 tons in 1884.

It has been stated sometimes in the technical and daily press that the metal track has not proved satisfactory, and is being either discontinued or actually removed. The perusal of the following pages will show clearly that the metal track is a success and that a supposed economy is the main reason for the comparative slowness with which it is being further introduced. The fact of the use of metal ties at switches and frogs on the Prussian state railways (see the end of the part of this report relating to Germany) is an evidence of the efficiency of the track and the favor with which it is regarded. In the only instance where metal track has been abandoned (on the Altona division of the Prussian State railways) it is officially stated that local conditions of the ballast and road-bed, and not any deficiencies of the track, have led to this action. The tracks laid with wooden ties are being improved by the extensive introduction of heavy metal tie-plates and improved fastenings for the rails. The wooden ties are usually treated with some preservative process. The administration of the Saxony State railways report that wooden ties are used almost exclusively upon these lines.

The extent of metal track on the Prussian State railways in 1886 and 1887 was as follows:

	1885-'86.		1886-'87.	
	Cross-ties.	Longitudinals.	Cross-ties.	Longitudinals.
	Miles.	*Miles.*	*Miles.*	*Miles.*
Main tracks	2,480	2,232	2,870.60	2,275.40
Side tracks	248	124	260.40	124.00
Total	2,728	2,356	3,131.00	2,399 40

New material was used as follows:

Year.	Iron ties and longitudinals.			Wooden ties.		
	Tons.	Total cost.	Cost per ton.	Number.	Total cost.	Cost per tie.
1885–'86	40,214	$1,356.067.00	$33.75	1,510,806	$1,784,246.25	$1.18
1886–'87	31,913	1,041,760.75	32.75	1,581,169	1,876,552.50	1.15

The following table gives the quantities of wooden and iron ties laid in 1886, 1887, and 1888:

Prussian state railways.

Year.	Wooden ties.	Metal ties.	Wood.	Metal.
	No.	*No.*	*Per cent.*	*Per cent.*
1885–'86	1,507,263	672,086	69.16	30.84
1886–'87	1,582,877	522,470	75.18	24.82
1887–'88	1,654,304	493,623	77.02	22.98

All railways in Germany.

Year.	Wooden ties.	Metal ties.	Wood.	Metal.
1885–'86	2,462,004	1,007,152	70.97	29.03
1886–'87	2,544,992	868,262	74.56	25.44
1887–'88	2,677,424	750,670	78.10	21.90

The following table gives the comparative mileage of different classes of track from 1880 to 1885:

Year.	Cross-ties.			Longitudinals—iron (mileage).	Total mileage.	
	Wood.	Iron.	Mileage.		Cross-ties.	Longitudinals.
	Per cent.	*Per cent.*			*Per cent.*	*Per cent.*
1880–'81	96.73	2.43	33,442	2,046.5	94.10	5.76
1881–'82	95.39	3.74	33,704	2,422.6	93.18	6.70
1882–'83	93.51	5.63	34,270	2,636.5	92.76	7.14
1883–'84	91.90	7.23	34,873	2,957.3	92.10	7.81
1884–'85	89.97	9.18	35,416	3,219.3	91.55	8.32

NOTE.—Small balance of length not accounted for.

About June, 1889, the following note on this subject appeared in "Kuhlow's German Trade Review:"

Metallic v. Wooden Ties in Germany.—As far back as last year the North-German group of the German Iron and Steel Manufacturers' Union and the German Ironmasters' Union addressed a petition to the minister of public works, in which the latter was requested to take steps so that the use of wooden ties should not only not become greater, but that the substitution of iron or steel ties for wood might be continued, as was the case in the previous year, and to proceed with the view to having everything connected with the railway lines only of iron and steel. The societies above named have recently again addressed themselves to the minister with the request that the latter do all in his power to put an end to the importation of foreign wooden ties, and to supply the deficiency thus created by an increased use of iron ties. The petitioners assigned a number of reasons for their action. The increase in the use of iron ties, which on the Prussian railways was 11½ per cent. on the quantity in use in 1883–'84, was only .53 per cent. on the other railways of Germany, while the German forest owners derived no benefit therefrom, as can be proven by the figures representing the yearly importation from abroad of wooden ties. The amount of wages lost by German railway workmen consequent upon importing ties from abroad is calculated at $1,392,187.50 and the loss caused by the diminution in the traffic on the state railways at $371,250. A reply to the petition has just been received from the minister of public works, in which he states that he is very glad when he can encourage the use of iron ties on the Prussian railways as formerly, but he is not in a position to accede to the request of the petitioners to exclude as far as possible the wooden ties. The wooden ties, particularly after the new improvements in the tie-plates and track fastenings, have proved themselves to be especially suitable as supports for the rails, while the iron ties hitherto supplied have not sufficiently justified their use on those portions of the line in which a fine or impervious material for ballast has to be reckoned with. When iron ties are produced which will obviate the difficulties attendant on their use in the cases named a large increase in their application will take place even on those lines on which they have been hitherto used only to a limited extent.

PRUSSIAN STATE RAILWAYS.—*Berlin division (province of Brandenburg).*—Metal longitudinals of the "Hilf" and "Haarmann" types are used (See plate No. 12), and at the end of 1884 there were 473 miles of this class of track in service. The Haarmann longitudinal, as now used, is in lengths of 29.49 feet, weighing 508.95 pounds, or 51.75 pounds per yard; it has the middle part about 4 inches wide, 2.08 inches deep, and .36 inch thick, with a rib on each side of the top table, forming a groove for the flange of the rail; the flanges of the longitudinal are inclined downwards toward the outer edge at a slope of 1 in 12 and the edges are bent down vertically to a depth of 1.18 inches; the width over the flanges is 12.8 inches. The rail clamps are short channel plates (⊏), with the top flange bearing on the rail and the bottom flange on the inner side of the longitudinal; the two clamps are held together by a bolt .76 inch diameter passing through the clamps and through the upper part of the longitudinal, under the rail. At the joints the ends of the longitudinals rest on a saddle plate of inverted channel section, with a deep groove rolled in the top table, which is inclined so as to make the outer side of the longitudinals higher than the inner side, and so give the rail the usual inward inclination. The lower flanges of the rail clamps pass through the top of the saddle, taking a bearing on the under side of the top table. The saddle is secured to a bed plate 19.28 inches wide and .40 inch thick, by bolted clamps on the Ruppel plan (See plate No. 13). The rails are of flange section, weighing 59.7 pounds per yard; they are 29.52 feet long and 5 inches high, with a flange 3.40 inches wide. The rail joints are spliced by deep angle-bars having a vertical web projecting below the rail. The weight of the track complete is 1,616.55 pounds per rail length, or 179.63 pounds per yard. This system of metal track is used on the Berlin City Railway.

The Haarmann combined rail and longitudinal has also been tried for a length 3.1 miles. This compound rail (See plate No. 12) was a large flange rail composed of two pieces placed side by side; it was 8 inches high over all, 12 inches wide over the flange, with a head 2.4 inches wide; the two parts were connected by two rows of rivets, and the joints were spliced by angle-bars 16 inches long, with eight bolts in two rows. The two parts of each rail broke joint by 20 inches. Flat tie-bars, with ends bent at right angles and secured by bolts passing through the webs of the rails, were placed at intervals of 9 feet 10⅛ inches. The weight of this track was 273 pounds per yard.

The following is Mr. Bricka's statement of the track of this division at the end of 1884:

	Miles.
Main lines	1,414.22
Local lines	163.68
Total track	2,762.72
Wooden ties	2,276.64
Metal longitudinals	473.06
Metal ties	1.24
Stone blocks, etc	11.78

Two systems of track are adopted for the bridges of the city railway, for the purpose of deadening the noise: (1) The rails rest on iron longitudinals, of the Haarmann type, connected by iron cross-tie connections, wooden packing blocks being placed between the two parts. A water-tight casing, hung below the floor, receives all water and drainage and is covered with a thin layer of gravel to deaden the noise from vibration. The wooden blocks are difficult to maintain. (2) The longitudinals are bedded in gravel laid in troughs along the bridge, the top of the longitudinal being level with the top of the trough. The floor is of buckle plates covered with gravel. This track is heavy and alterations cannot easily be effected for frogs and switches, while it is difficult to tamp the longitudinals properly.

PRUSSIAN STATE RAILWAYS.—*Elberfeld division (province of Westphalia)*.—This division includes most of the lines in the industrial district of the Rhine, in Westphalia, and has a heavy traffic on its principal lines. It also includes the former Berg and Mark Railway, the name of which is well known in connection with metal track, this road having been one of the first to experiment on a large scale with such track. The following is Mr. Bricka's statement of the track for 1884:

	Miles.
Main lines	587.76
Local lines	159.96
Total track	1,590.30
Wooden ties	912.02
Metal longitudinals	41.54
Metal ties	629.30
Stone blocks, etc	7.44

The first trials made in Germany with metal ties were made on the old Berg and Mark Railway. The trials were commenced in 1869, with ties of the original "Vautherin" type; these were 3.2 inches wide on top, 6.8 inches wide inside on the bottom, and 9.2 inches wide over the flanges; 2.4 inches deep; the sides and top were .24 inch thick and the flanges .32 inch thick; the weight was 40.70 pounds; the ends were open. This type not proving satisfactory, changes were made which led to the designing of the "Berg-and-Mark" (or Bergisch-Markische) type of tie. It is a modification of the "Vautherin" type, doing away with the narrow horizontal flanges at the bottom, and having the lower part of the sides bent to a vertical position (See plate No. 12). The tie was 7.5 feet long, 5.2 inches wide on top, 9.2 inches wide on the bottom, and 2.4 inches deep, with the sides vertical for 1 inch from the bottom; the thickness was .24 inch at the bottom, increasing to .36 inch at the top, and on the under side of the top table was a rib 1.44 inches wide, making the thickness .52 inch to give extra strength at the holes for the fastenings. The tie was horizontal for a length of 3 feet $3\frac{3}{8}$ inches at the middle, and then inclined upward 1 in 20 to the ends, which were closed by bending over the top table. The weight of the tie was 98 pounds, and of the fastenings 5.4 pounds, making a total of 103.4 pounds per tie. The rails were of flange section, weighing 66 pounds per yard, and having a flange 4 inches wide. The fastenings of each rail consisted of three gibs and a cotter (See plate No. 13). The outer flange was held by a gib, the lower side of which bore on the inside of the tie; a similar gib held the inner flange, and a small gib was placed against the opposite side of the hole in the tie, so as to give a good bearing for the cotter, which was driven down vertically between these two gibs. The cotter was about $6\frac{1}{2}$ inches long, eleven-sixteenths-inch thick—$1\frac{5}{32}$ inches wide at top and thirteen-sixteenths inch wide at $1\frac{3}{32}$ inches from the end, thence tapering to a point; the side furthest from the rail was perpendicular to the top of the tie. The gibs were all eleven-sixteenths inch thick; the outer and the small inner gibs were made in three different widths, to allow for the adjustment of the gauge at curves, etc. At the rail joints the ties were spaced 20.4 inches apart, center to center.

Metal ties only are now used for main lines; metal and wooden ties are used for branch and local lines. The ties for main lines are of the modified Berg-and-Mark type (See plate No. 12). They are 8.2 feet long, 4.4 inches wide on top, 8.72 inches wide inside at the bottom, and 9.36 inches wide over the ribs on the bottom edges; they are 3 inches deep, with the sides nearly vertical for 1.5 inches from the bottom; the sides are .28 inch thick; the top table is .36 inch thick, with a strip along the middle .52-inch thick for a width of 1.44 inches, the extra metal being added on the under side. The middle part of the tie is horizontal for a length of 3 feet $3\frac{3}{8}$ inches, and is then inclined upward 1 in 20 to the ends, which are closed by bending down the top table. The weight is 119.24 pounds per tie. There are 10 ties to a rail length of 29.52 feet; the joint ties are spaced 24 inches apart center to center, and the intermediate ties 37.04 to 37.08 inches apart. The rail fastenings are gibs and cotters arranged as above described; the outer gib weighs .75 pound, the inner gib .68 pound; the small gib .26 pound, and the cotter .97 pound. The rails are of flange section, 29.52 feet long, weighing 67.2 pounds per yard; they are 5.36 inches high, and have a flange 4.20 inches wide. The weight of the track is 2,696.93 pounds per rail length, or 274.08 pounds per yard. The ties for local lines are of the original Berg-and-Mark type; 8.2 feet long, 5.2 inches wide on top, 9.2 inches wide on the bottom, 2.4 inches deep, with the sides vertical for 1 inch from the bottom; the sides are .28-inch thick, and the top table .36-inch thick, with a rib along the under side, making it .52-inch thick for a width of 1.44 inches. They are bent to shape and have the ends closed in the same way as the heavier ties. The weight is 106.26 pounds per tie, and the track weighs 2,567.13 pounds per rail length, or 260 pounds per yard.

The following is a detailed statement, furnished in July, 1888, by the officers of the division for the purpose of this report:

This division includes the former Berg-and-Mark Railway, and in 1887 it comprised about 806 miles of line, with about 1,649.20 miles of main and side tracks, laid as follows:

	Miles.
Wooden cross-ties	790.50
Metal cross-ties	762.60
Metal longitudinals	93.00

The lines are divided into two classes, according to their traffic; main lines, generally with double track, with a maximum grade (exceptionally) of 1 in 75, or 1.33 per cent., and a minimum curvature of 984 feet radius; local or branch lines, with single track, a maximum grade of 1 in 40, or 2.5 per cent., and a minimum curvature of 590.40 feet radius.

The first trial of iron cross-ties was made in 1869 by the Berg-and-Mark Railway. In 1874 they were used to a larger extent, and in 1877 a further introduction of them was commenced. Iron longitudinals have not been laid on the lines of this division, but in 1880, when all the Prussian railways were acquired by the Government, the boundaries were extended, and so included parts of some lines using these longitudinals. On main lines the traffic is about one hundred and sixty trains per day (on double track), at speeds of 46.5 miles per hour for passenger trains and 27.9 miles per hour for freight trains; the six-wheel engines weigh about 42 tons, with 7 tons on the driving wheels. On branch lines the traffic is from twenty-five to thirty trains per day, at a speed of 18.60 miles per hour for passenger and freight trains. The six-wheel engines weigh about 30 tons, with 5 tons on the driving-wheels.

The ties are now made of mild steel, and for their manufacture the basic process of Thomas Gilchrist has recently been used; no preservative process has been used; the ties are laid in the condition they leave the rolls, and there is very little trouble from rust. They are manufactured by a number of works, proposals being advertised for in the usual way. The cost at the mills in 1888 was from $27.50 to $30 per ton, or about $1.50 to $1.62½ per tie for main lines and $1.32½ to $1.45 per tie for branch lines. The gibs and cotters, being of wrought-iron, cost at the same time $72.50 per ton. The cost of maintenance of the ties is very small, as the works furnishing the ties must give a guaranty for two years, replacing every tie which becomes damaged during this time. If a tie has internal defects which escape notice at the inspection, they will show themselves within two years, and it is found that after that any failure of the ties now used is very rare. On the other hand, the labor for the maintenance of track on metal ties is considerable, and is greater as the ballast is less hard and less porous. This is especially the case during the first few years, until the track has settled to a firm bearing. It seems, therefore, that metal ties require the best broken stone ballast, and with this material the cost of maintenance of track on metal ties is scarcely greater than that of track on wooden ties, especially as the item of renewals (necessary for wooden ties in a few years) is eliminated. Exact comparisons between the cost of maintenance of track on metal and wooden ties on this division cannot be made, as the expenses are not separated, and there are wooden ties only on branch lines and on main lines with little traffic. All tracks having considerable traffic are now laid with metal ties. There has been no experience as to the life of metal ties. With the present form of tie there are no breakages under ordinary circumstances, and there is no weakening by rust discernible, not even with the older ties. Wherever a renewal has been necessary it has been on account of the enlargement of the holes in the tie by wear or of a crack between the holes. In no case can it be said that metal ties last longer than wooden ties.

[In this connection, however, it may be remarked that wooden ties in Europe have a much longer life than in this country, from fifteen to twenty years or more, owing to the use of rail chairs, broad tie-plates, and preservative processes.—E. E. R. T.]

As remarked above, metal ties require ballast of the best quality. On this division broken stone of a hard and durable character is used; this material costs from 62½ cents to $1.12½ per cubic yard according to locality, while gravel ballast for wooden ties costs only 25 to 62½ cents per cubic yard. The experience here is that metal ties have a tendency to grind the softer ballast to dust, which in wet weather becomes mud. If the ballast consists of soft clayey gravel, the cost of maintenance is proportionately greater. Without ballast metal ties could not be used at all. [They are, however, successfully used under such conditions in Australia. See "Queensland."—E. E. R. T.] On the other hand, ballast of hard broken stone forms a solid hard body in the interior of the tie, which contributes considerably to the firm bedding of the track. For main lines there is a bottom course of large stones and the smaller material is brought up level with the tops of the ties; it is 21.97 feet wide on top (for double track), with side slopes of 1 to 1½ and a depth of 14 inches at the middle; the subgrade is crowned to an inclination of 1 in 25. For local lines the style of construction is the same; 10.5 feet wide on top with side slopes of 1 to 1, and a thickness of 6 inches under the tie at the middle. The attachments of the rail do not cause any difficulty; on the contrary, the position of the rails is more securely maintained than with wooden ties, and any loose fastenings can be easily tightened by driving the cotters, while with wooden ties respiking would be necessary.

An impulse to the general use of iron ties on this division was given by the hard times of the home iron industry at the end of the last decade; in consequence of which the prices were so low that iron ties were actually cheaper than wooden ties, which had to be imported, as the home forests could not supply a sufficient quantity. The use of metal ties was also, partly from a patriotic motive, to help the iron industry. The experience with these ties was in general satisfactory, and their use was therefore continued. The dephosphorizing of the poorer German ores by the Thomas Gilchrist process has also been favorable to the use of metal ties by reducing the price for mild steel. Oak ties for main lines cost $1.37½ each, or $1.50 if impregnated with chloride of zinc; for branch lines some impregnated beech ties have been used, costing 96 cents each. The life of wooden ties varies between five and fifteen years; a life of ten years is rare even for oak ties, as on account of the occasional respiking they become weakened, even if still sound. The value of old material must be taken into account, for while old wooden ties are practically of no value, old iron ties can be sold for $11.25½ to $12.50 per ton, or about 62½ cents each. On the whole, metal ties appear to be as serviceable as wooden ties; a disadvantage consists in their less elasticity, as riding over them feels harder to the passengers; but they have the advantage of a firm and accurate rail fastening. The climate is uniform and moist, having about the same effect upon wooden and metal ties. On the strength of our experience we can consider metal ties only equal to the best wooden ties. It will depend upon local circumstances whether their use will be economical; if, as in our district, the first cost is not much higher, and if there is good material for ballast available at a low price, then the use of metal ties may be considered advantageous and economical on account of their longer life and their value as old material.

PRUSSIAN STATE RAILWAYS.—*Cologne Division, right bank of the Rhine (province of the Rhine, or Rhenish Prussia).*—Metal track of different types has been tried on this division since 1868. A longitudinal used was similar to the "Vautherin" type of cross-tie; it was $8\frac{11}{16}$ inches wide on top, $11\frac{13}{16}$ inches wide on the bottom, $2\frac{3}{8}$ inches deep, five-sixteenths of an inch thick on top; the weight was 46.36 pounds per yard. Cross-ties of similar form were also used; they were 7 feet $4\frac{9}{16}$ inches long, $3\frac{15}{16}$ inches wide on top, $8\frac{11}{16}$ inches wide at the bottom, $2\frac{3}{8}$ inches deep, five-sixteenths of an inch thick on top; the weight was 77.16 pounds per yard, or 82.76 pounds including the fastenings. These were manufactured by the Gutehoffnung works at Oberhausen. The longitudinals were closed at the ends by angle-pieces bolted on; the gauge was maintained by means of tie-rods of round iron passing through the webs of the rails and having a washer and nut on each side of each rail; the rails were fastened by clamps and bolts. The rail joints were even and suspended, spliced by angle bars and channel bars. With the cross-ties, the rails of flange section were secured by bolts and clamps similar to the Ruppel plan (See plate No. 13). The ties were bent up at the ends to give the rails an inward inclination. For a rail length of 21 feet $8\frac{1}{4}$ inches, the ties were spaced $21\frac{3}{4}$ inches apart, center to center at the joints, $32\frac{7}{8}$ inches next to the joints, and $39\frac{3}{8}$ inches intermediate, giving eight ties to a rail length. The rail joints were even and suspended and were spliced by angle bars.

Cross-ties of the "Haarmann" type (See plate No. 12), have been in use for some years on the Cologne and Minden line; they are 7 feet $10\frac{1}{2}$ inches long, the middle part is $4\frac{5}{16}$ inches wide on top and $1\frac{15}{16}$ inches deep, the width over the bottom flanges is $9\frac{13}{16}$ inches, and the edges of the flanges are turned down for a depth of thirteen-sixteenths of an inch; the thickness of the top is three-eighths of an inch. The ends of the tie are bent upward, and the extremities are closed by bending down the top table, instead of by riveted pieces; the rail fastenings consist of bolts and clamps on the Ruppel plan. The weight per tie is 108 pounds, or 113.9 pounds including the fastenings. For a rail length of 30 feet the ties are spaced $20\frac{1}{2}$ inches apart, center to center, at the joints, $33\frac{5}{8}$ inches next to the joints, and 39 inches intermediate. The Haarmann system of longitudinals has also been used. The longitudinals were 3.92 inches wide at top and bottom of the "cap," 2.08 inches deep; the width over the flanges was 12.8 inches, and the total depth 3 inches; thickness of the flanges, sides and top table was .24, .28, and .36 inch. The weight was $47\frac{1}{2}$ pounds per yard. The track is similar to that of the Berlin Division, already described. The longitudinals were 29.52 feet long, laid with even joints, but breaking joint with the rails. At each joint was an angle iron cross-tie, 6.23 feet long; at each end of it was a saddle to which the ends of the longitudinals were fastened.

The following is Mr. Bricka's statement of the track for the end of 1884:

	Miles.
Main lines	920.08
Local lines	234.36
Total track	2,241.92
Wooden ties	1,758.94
Metal longitudinals	124.62
Metal ties	347.20
Stone blocks, etc	11.16

Iron cross-ties of the modified "Berg-and-Mark" type (See Plate No. 12) are now in use on this division. They are 8.2 feet long for heavy ballast, or 8.85 feet long for light ballast; 5.2 inches wide on top, 9.44 inches wide at the bottom, 3.2 inches deep, with the ends 3.6 inches deep; the thickness of the sides is .28 inch, and of the top table .32 inch. The tie is horizontal, but at each rail seat is a tie-plate giving the rail the usual inward inclination; the outer end of this plate has an **S**-shaped lug, the top part holding the outer side of the rail-flange, and the lower part passing through a slot in the tie and bearing on the underside of the top table. The inner flange of the rail is held by a bolt and clamp on the Ruppel plan, the lug of the clamp passing through the bolt-holes in the tie-plate and tie. The joint ties are spaced 26.68 inches apart, center to center; and the intermediate ties 37 to 37.04 inches. The rails are of flange section 29.52 feet long, 5.36 inches high, with a flange 4.20 inches wide; they weigh 67.2 pounds per yard. The rail-joints are spliced by deep angle-plates, having a web projecting below the rail, the ends of this web being cut to fit the slope of the side of the tie; there are four bolts to each joint. The track, with ties 8.2 feet long, weighs 2,750.09 pounds per rail length, or 305.58 pounds per yard.

In June, 1888, there were altogether 612.75 miles laid with metal track, 450.69 miles with cross-ties, 153.78 miles with longitudinals not having cross-tie connections, and 8.28 miles with longitudinals having such connections. There are also on one of the local lines 7.8 miles of the Hartwich system of combined rail and longitudinal, laid directly in the ballast.

PRUSSIAN STATE RAILWAYS.—*Cologne Division, left bank of the Rhine (province of the Rhine, or Rhenish Prussia).*—On this division metal track has been used very extensively, and several different forms of track have been tried. Metal cross-ties are now exclusively used for renewals and new work. The following is Mr. Bricka's statement of the track for the end of 1884:

	Miles.
Main lines	850.02
Local lines	168.64
Total track	2,117.30
Wooden ties	1,212.10
Metal longitudinals	252.34
Metal ties	639.84
Stone blocks, etc	13.02

Of longitudinals the "Hilf," "Rhenish," and "Haarmann" types have been used, but no new track of this kind is now laid. Of cross-ties the Vantherin type was first used, then the Rhenish, the original Berg-and-Mark, the modified form of the "Berg-and-Mark," and the "Haarmann" tie. The modified form of the Berg-and-Mark type was considered the best. The "Haarmann" tie was ordered by the minister of railways to be used on most of the divisions of the State railways, but it is reported that it has not given as much satisfaction as some other systems, and its use is not being extended. The ties of this type used on this division were 7.8 feet long, with the middle part horizontal, and the ends inclined upward 1 in 20 for a length of 26 inches. It was 4.4 inches wide on top and 4.8 at the bottom of the "cap," 2 inches deep; 10 inches wide over the flanges and 2.56 inches deep over all; the thickness varied from .28 inch to .36 inch. A piece of N-iron (or double-angle iron) was riveted inside at each end and at the middle. The weight of the tie was 110 pounds. With cross-ties of the modified "Berg-and-Mark" type the Haarmann system of combined tie-plate and fastening has been used, as already described for the Right Bank of the Rhine Railway.

A special return from this division was furnished in 1888 for the purpose of this report, as follows:

Of the 1,681.81 miles of line, 943.96 miles were laid with metal cross-ties and 241.45 miles with metal longitudinals, the remainder being still on wooden cross-ties. The track on longitudinals included 43.44 miles of the Rhenish type, 1.86 miles of the Haarmann type, and 200.57 miles of the Hilf type, a total of 245.87 miles, of which about 5 miles of the first two types were for experiment. The first longitudinals were laid in 1872 and the first cross-ties in 1876.

The division has 30 per cent. of its length horizontal and 70 per cent. on grades; the steepest grade is 1 in 37, or 2.7 per cent. In alignment there are 65 per cent. of tangents and 35 per cent. of curves; the sharpest curve has a radius of 590.40 feet. The traffic consists of passenger and freight trains, some of the former being express trains. The standard four-coupled passenger engines weigh 37 tons, having 24.4 tons on the two driving axles and 12.6 tons on the leading axle or truck; the tender weighs 27.5 tons. The standard six-coupled freight engines weigh 38.5 tons, and their tenders 27.5 tons. The standard six-coupled tank engines for branch or local lines weigh 29.2 tons.

The ties are of mild low-carbon steel, and are not painted or otherwise treated. They are manufactured by the Aachen Mills; the Phœnix Company, of Laar; the Union Company, of Dortmund; the Rhenish Steel Works, of Ruhrort; and the Good-Hope Works, of Oberhausen. The cost, delivered, is about $31.25 per ton. In regard to maintenance, every mile of track on metal longitudinals requires about 372.58 days' labor of one man per annum (231 days per kilometer), and every mile of track on metal cross-ties requires about 267.74 days' labor of one man per annum (166 days' labor per kilometer). The adjustment or widening of gauge at curves is effected by means of different sizes of rail clamps without varying the holes in the ties. The observations as to durability are not yet concluded. The ballast consists principally of river gravel, but broken stone is used in some places. It is satisfactory for cross-ties, but with longitudinals care must be taken to provide proper drainage. The principal reason for adopting metal ties was their advantage in maintaining the width of gauge accurately, and the convenience of track laying and tamping was also considered. In localities poor in wood the cheaper cost and at least the same, but probably longer, life than that of impregnated wooden ties must be taken into account.

The general results have been very satisfactory. There has been no trouble with maintenance, or with the rail attachments, which are much more secure than the ordinary spikes in wooden ties. No trouble has been experienced from breakages. With metal track the ties are more durable, so that the track is more economical; and the fastenings are more efficient, so that the track is safer than track on wooden ties.

Impregnated oak ties cost, exclusive of the value of old material, about $1.75 each, or about $3,104.84 per mile. They have an average life of about twenty years. The simplest testimony as to the opinion of the advantages of metal and wooden ties is that since 1879 no wooden ties have been purchased, iron ties having been used exclusively.

The drawings accompanying this communication show cross-ties of the "Haarmann" and the modified "Berg-and-Mark" types. The latter are 9.36 inches wide on the bottom, 3 inches deep over all, with the sides and top .28 and .36-inch thick respectively; the weight is 110 pounds. The former are 4.4 inches wide on top and 4.24 inches wide inside at the bottom of the "cap," 10 inches wide over the flanges; the middle part, or "cap," is 1.64 inches deep, and the flanges are turned down .80 inch, making the total depth over all 2.56 inches; the flanges are .24 inch thick, the sides .28 inch, and the top table .36 inch; the weight is 110 pounds. Both these forms of ties are 7.87 feet long, horizontal at the middle for a length of 3.6 feet, and then inclined upwards to the ends at an inclination of 1 in 20. No tie-plates are shown, the rails resting directly on the ties and being secured by bolted clamps on the Ruppel system. The rails are 5.36 inches high and 4.20 inches wide over the flange; the rail joints are even and suspended, and are spliced by deep angle bars, projecting below the rail, with four bolts. For a rail length of 29.52 feet the ties are spaced 26.68 inches apart, center to center, at the joints, 33.76 inches next to the joints, and the intermediate ties 38 inches.

Cross-ties of the "Hoerde" or "Post" type have also been used.

The system of rail attachment designed by Mr. Ruppel, of this division, is in extensive use and has given general satisfaction. (See Plate No. 13.) The rail is held by a clamp of such form that while the inner side bears on the rail flange the outer side bears on the top of the tie; on the under side of the outer edge is a lug or projection which fits into the bolt hole in the tie. The bolt passes up through the tie and clamp, and the nut is secured down on the latter; the head of the bolt is of ⊥-shape, so that the bolt can be put in or taken out without disturbing the ballast or the tie. The adjustment of the gauge at curves, etc., is effected by using clamps with lugs of different widths fitting into the bolt holes.

PRUSSIAN STATE RAILWAYS.—*Frankfort-on-Main division (province of Nassau).*—Metal longitudinals of the "Hilf" type were used in 1868 on the Nassau State Railway, now a part of this division of the Prussian State Railways. The following is a brief notice of the several different systems of metal track which have since been tried:

Cross-ties: (1) Ties of the original "Vautherin" type, with gib and cotter fastenings, open ends, and a piece of T-iron riveted across the bottom of the tie under each rail; (2) ties of similar section, but with bolted clamp fastenings and having the ends closed by riveted angle pieces (as on the left bank of the Rhine Railway; (3) ties of the "Berg-and-Mark" type, with bolted clamp fastenings and with an angle iron riveted inside the tie under each rail; (4) similar tie and fastenings, but with the ends closed; (5) ties of the original "Vautherin" type, with bolted clamp fastenings and with the top table bent down at the ends; (6) ties of Haarmann section, with bolted clamp fastenings and closed ends, 1881; (7) modified form of "Haarmann" tie, with the upper part wider and flanges narrow; bolted clamp fastenings, ends closed by riveted angle pieces, 1885; (8) similar to No. 7, but with the top table inclined at the rail seats.

This is the form of metal cross-tie adopted in 1887, as noted further on: Longitudinals, (1*a*) "Hilf" type, two forms of sections, one with middle rib, the other without the middle rib and resembling the original "Berg-and-Mark" cross-tie; the joints of rails and longitudinals coincided and round tie rods maintained the gauge; (1*b*) longitudinals with middle rib; they were not brought close to the rail joints, but a cross-tie of similar section was placed on each side of the joint; (1*c*) longitudinals and rails laid to break joint, with a cross-tie of similar section under the rail joints; (1*d*) similar track, but with the cross-ties placed back from the rail joints; (1*e*) joints of longitudinals and rails coincided; a cross-tie or similar section was placed under the joints and had a saddle support for the longitudinals; (1*f*) similar to No. 1*e*, but with the addition of a T-iron cross-tie at the middle of the rails. This is the form of metal longitudinal track adopted in 1888, as noted further on. (2) Longitudinals of Hilf section, with joints coinciding with rail joints, and an angle iron cross-tie fastened to the rails at the joints; (3*a*) similar longitudinals, with T-iron cross-ties under the joints and a saddle for the longitudinal; (3*b*) similar to No. 3*a*, but with a different seat for the longitudinals and with cross-ties of the Lasard section (T) under the joints; (3*c*) similar to No. 3*b*, but with a T-iron cross-tie on each side of the joints; (4) similar in general to No. 3*c*. The following is Mr. Bricka's statement of the track for the end of 1884:

	Miles.
Main lines	639.84
Local lines	37.20
Total track	1,468.78
Wooden ties	790.50
Metal longitudinals	634.88
Metal ties	37.82
Stone blocks, etc	5.58

Metal cross-ties and longitudinals are now in use for main lines. The former are of the "Haarmann type" (See Plate No. 12) 8.2 to 8.86 feet long, 6.4 inches wide on top, 7.2 inches wide at the bottom of the cap, 9.2 inches wide over all; the depth is from 2.8 inches at the ends and middle to 3.4 inches at the inclined rail-seat; the weight is 112.4 pounds per tie for the shorter, and 127.93 pounds for the longer, ties. There are ten ties to a rail length; the joint ties are spaced 28 inches, center to center; the next ones 33.12 inches, and the intermediate ties 37.96 inches. The rails are of flange section and the joints are spliced by deep angle-bars. The fastening for the rails consists of a bolt with a gauge-washer against which the rail flange abuts, and a channel-shaped clamp fitting over the washer and bearing on the tie and rail-flange. It is somewhat similar to the fastening used on the Baden State railways (See plate No. 13), but with the exception that the gauge-washer fits into the bolt-hole in the tie, having an eccentric head which rests on the top of the tie. This system of fastening appears to combine the advantages of the Ruppel and Baden systems; the gauge-washer by fitting into the bolt-hole adding greatly to the solidity of the fastening and reducing the strain on the bolt. The weight of this track is 2,815.30 pounds per rail length or 286 pounds per yard.

The longitudinals now used are of the Hilf type (See plate No. 12). They are 29.38 feet long, 7.2 inches wide on top, 12 inches wide at the bottom, 2.6 inches deep, with the top table .52-inch thick. The weight is 674.75 pounds, or 69 pounds per yard. The rails are of flange section, and the fastenings consist of bolted clamps of channel shape (┌─┐) which bear on the longitudinal and the rail flange. Under the rail-joint is a cross-tie of the same section as the longitudinal; it is 8.53 feet long, and weighs 196 pounds. The cross-tie is under the longitudinals, which are fastened to it by large angle clamps (──┐), with bolts passing through the cross-tie and the horizontal part of the clamp. Two channels are riveted across each end of the cross-tie and support the top table of the longitudinal from the inside. At the middle of the rail length is a T-iron cross-tie, 8.2 feet long, 5.6 inches wide, 6 inches deep, and weighing 154 pounds or 66.34 pounds per yard. On curves of less than 1,640 feet radius two of these cross-ties are used. The weight of this track is 3,040.75 pounds per rail length of 29.52 feet, or 337.85 pounds per yard.

In September, 1889, the officers of this division stated that the Hilf system of longitudinals will in future be used only to a small extent on a certain part possessing excellent material for ballast, which lets the water drain off quickly. Iron cross-ties are used on parts where stone ballast is readily obtainable. Where the road bed is in clayey or loamy sand wooden ties are used exclusively on new branch and local lines. For the renewals on all lines during 1889 about an equal number of iron and wooden ties were used.

PRUSSIAN STATE RAILWAYS.—*Erfurt division (province of Thuringia)*.—Various systems of metal track have been tried on this line, both with longitudinals and cross-ties, but the latter have now been definitely adopted. In October, 1889, the officials of this division forwarded a detailed statement in regard to their experience with metal track.

Metal ties were first laid in 1879, and there are now 251.10 miles of track on seven sections of the line. The grades are from 0 to 1 per cent., and the curves down to 984 feet radius. The traffic consists of passenger and freight trains, the express passenger trains running at 43½ miles per hour. The heaviest six-coupled freight-engines weigh 40 tons in working order.

The ties are manufactured by the Hösch Iron and Steel Works, of Dortmund; the Mine and Mill Company, of Hörde, and the Queen Marie Works, of Cainsdorf, Saxony. The cost is $33.75 per ton at the works. No preservative treatment is employed, the ties being laid in the state in which they come from the rolls. It is estimated that the metal track will last thirty years, while wooden ties must be renewed every twelve or fifteen years. The reasons for the adoption of metal ties were as follows: (*a*) the maintenance is cheaper than that of track on wooden ties; (*b*) the price is cheaper, taking into consideration the durability of thirty years, than that of wooden ties; (*c*) the encouragement of the iron industry. The general results have been satisfactory, and there has been no trouble with maintenance, with the rail attachmnts, or from breakages. The wooden ties are of pine or oak; impregnated pine ties cost 87.5 cents per tie and last about ten to twelve years; oak ties cost $1.37½ each and are estimated to last fifteen to eighteen years.

Arrangements have been made for giving up entirely the use of the Hilf longitudinal system after a lapse of not more than five years. At the same time that the longitudinals were first laid, in 1879, the laying of metal cross-ties was also commenced, and there are at present 251.10 miles of main track laid with them, equal to 17 per cent. of the total length of track of this division. In selecting the sections of the line to be laid with these ties, the quality of the ballast was taken into consideration, to provide proper drainage. The form of the tie now used has been arrived at by the development of the original form according to the experience obtained. The earlier ties were of the "Haarmann," "Hilf," and the original "Berg-and-Mark" types.

The "Haarmann" ties were 7.87 feet long, and weighed 113.65 pounds each; they were 4.4 inches wide on top, 4 inches wide inside at the bottom of the "cap," and 10 inches wide over the flanges; the sides of the flanges were bent down .8 inch, making the depth over all, 2.56 inches. The vertical parts of the flanges were .20 inch thick; flanges, .24 to .28 inch; sides, .28 inch, and top table, .36 inch thick. The ends were closed by riveted pieces of double-angle section (┌───┘), the upper web fitting inside the "cap" of the tie, the flange riveted under the flanges of the tie, and the lower web projecting below the end of the body of the tie; the total depth at the ends was 3.40 inches. The tie was horizontal at the middle, and inclined upward 1 in 20 to the ends; as this was found to render the track unstable, the tie was afterward made horizontal, with the rail-seat inclined 1 in 20 by the Hosch-Lichthammer system. (See "Holland.") The fastenings were of the Ruppel type, already described.

The Hilf ties were 7.87 feet long, and weighed 114.4 pounds each; they were 4.8 inches wide on top, 8.8 inches wide at the bottom, 2.4 inches deep, with the sides vertical for 1.2 inches from the bottom; the sides were .32 inch and the top table .40 inch thick; the top table was bent down at the ends to a depth of 4 inches, and the sides were bent round outside at the end. The ties were of similar shape, longitudinally to the Haarmann ties, and the same fastenings were used.

The "Berg-and-Mark" ties were 7.54 feet long, 5.2 inches wide on top, 9.2 inches wide at the bottom, 2.4 inches deep, with the sides vertical for 1 inch from the bottom; the sides were .28 inch thick, and the top table .36 inch; with a rib 1.44 inches wide on the underside, making the thickness .52 inch. The weight was 97.90 pounds per tie. The tie was horizontal at the middle and then bent up at an inclination of 1 in 20 to the ends, which were closed by bending down the top table. Gib and cotter fastenings were used.

The ties now adopted are a modification of the Haarmann type, having the "cap" wide and the flanges narrow. They are 8.85 feet long, and weigh about 126.50 pounds each; the ends are flared out and are closed by bending down the top table; they are horizontal throughout. They are 6.4 inches wide on top, 7.2 inches wide inside at the bottom of the cap, 9.2 inches wide over the flanges, and about 11.2 inches wide over all at the ends; the depth of the cap is 1.84 inches, and 2.8 inches over all; the depth at the ends is 4.8 inches. The sides are .28 inch thick, and the top table .32 inch. The fastenings are of the Haarmann type already described, the rail resting on a tie plate with a hooked lug at the outer end, and a bolted clamp on the inner end. The plate is 6 inches long and 7.08 inches wide over all; and from .28 inch to .5 inch thick. There are ten ties to a rail length of 29.52 feet; the joint ties spaced 26.68 inches center to center, and the intermediate ties about 37 inches. The weight of the track is 2,854 pounds per rail length, or 290.1 pounds per yard.

In renewals on existing lines on this division about 50 per cent. of the ties used are of iron and the balance of wood. On new lines, however, preference is given to wooden ties on account of their less cost. The wooden ties used are generally of pine, imported from foreign countries, as the forests of this country can not supply the great demand.

PRUSSIAN STATE RAILWAYS.—*Altona Division* (*Province of Schleswig-Holstein.*)—Trials of metal track have been made on a small scale, and some of the Hoerde or Post steel cross-ties have been tried. The following is the substance of a statement made by the officers of this division in August 1889:

> On this division metal track has been tried only to a limited extent; but even on the short stretches of road where iron ties were used they have been replaced by wooden ties, because the ballast and road-bed of this division have proved to be unsuitable for iron ties.

This official statement suggests two comments: First, it has been reported from time to time in the technical and other papers that metal ties have not been a success in Germany and have been abandoned. This has been through ignorance in taking the experience on one division as representing that on the entire railway system. The other official statements which are given in this report show that on the whole the metal ties are giving good results and are being extensively adopted, after years of experience and experiment. Second, the statement shows very clearly that the metal ties will not of themselves necessarily make a good track, since their abandonment on this division is due primarily not to any defect in the ties (the type used is not stated), but to the material of the ballast and the road-bed.

PRUSSIAN STATE RAILWAYS.—*Hanover Division* (*Province of Hanover*).—Longitudinals of the "Hilf" type were first used in 1876 and "Haarmann" longitudinals in 1880. At the end of 1884 there were 340.38 miles of track on longitudinals, of which 154.38 miles were on the Hilf system. The track is similar to that of the Berlin division, already described. In 1888 there were 222.3 miles of the Haarmann and 142.84 miles of the Hilf type. Metal cross-ties were first used in 1878, and their use has been continued. The "Vautherin," "Rhenish," and "Haarmann" types of ties have been tried. The latter are similar to those on the Erfurt division, with the rail seat formed on the Hosch-Lichthammer plan. The Haarmann fastenings, with the hooked tie-plate, and the Ruppel fastenings, with bolted clamps, are both used.

The following is Mr. Bricka's statement of the track for the end of 1884:

	Miles.
Main lines	1,124.68
Local lines	101.06
Total track	2,570.52
Wooden ties	2,117.92
Metal longitudinals	340.38
Metal ties	107.26
Stone blocks, etc	4.96

PRUSSIAN STATE RAILWAYS.—*Magdeburg Division* (*Province of Saxony*).—In 1879 trials were made with cross-ties of the same section as the Hilf longitudinal. Then the "Berg-and-Mark" tie of the Elberfeld division was tried, and later the Haarmaann tie. The latter weighed 112.2 pounds, were bent up at the ends to give the inclination to the rails, and had the Ruppel system of fastenings. The "Hoerde" or "Post" tie has been tried within recent years.

The following is Mr. Bricka's statement of the track for the end of 1884:

	Miles.
Main lines	858.08
Local lines	73.16
Total track	1,920.76
Wooden ties	1,780.64
Metal longitudinals	13.02
Metal ties	126.48
Stone blocks, etc	.62

PRUSSIAN STATE RAILWAYS.—*Breslau Division* (*Province of Silesia*).—On this division, cross-ties of the modified Berg-and-Mark system have been tried. They are 8.2 feet long, 4.4 inches wide on top, 7.76 inches wide inside at the bottom, 9.12 inches wide over all at the bottom, 3 inches deep; thickness of sides, .32-inch, and of the top table .36 inch. The weight is 120 pounds per tie. The ends are inclined upward 1 in 20. The rail fastenings consist of clamps and bolts on the Ruppel plan. The joint ties are spaced 26.68 inches, center to center, and the intermediate ties about 37 inches. The weight of the track is 2,704.77 pounds per rail length, or 274.86 pounds per yard.

In November, 1888, a contract for 599 tons of metal ties was awarded to the Laurahutte Works at $31.25 per ton at the works.

PRUSSIAN STATE RAILWAYS—*Bromberg Division* (*Province of East Prussia*).—Metal cross-ties and longitudinals are in use on this division. Of the latter there were, in 1888, 116.12 miles of the Hilf system with heavy cross-tie connections; 43.64 miles of the Hilf system without these connections, and the ends of the longitudinals resting on a saddle plate, and 32.17 miles of the Haarmann system.

BAVARIAN STATE RAILWAYS.—Different systems of metal track have been tried on these lines, partly to reduce the expenses for maintenance and renewals, and partly in the interest of the iron industry of the State. The Hartwich system of track has been tried (see plate No. 12); also the Hilf and Rhenish systems of longitudinals. The types of cross-ties tried include the "Vautherin" (weighing 77 pounds per tie); the Haarmann (102.3 pounds;) the "Berg-and-Mark," with rail seat inclined on the Hosch-Lichthammer plan (114.4 pounds); and the "Heindl" (138.6 pounds). The engineers have recognized the superiority of cross-ties over longitudinals for main lines, but the latter are still used to some extent on secondary lines. In June, 1888, contracts were let for 11,100 tons of metal ties at about $29.10 per ton.

Mr. Bricka, in his report, gives the following statement of the track for the end of 1884:

	Miles.
Main lines	2,401.26
Local lines	327.98
Total track	3,727.44
Wooden ties	3,232.06
Metal longitudinals	275.90
Metal ties	10.54
Stone blocks, etc	208.94

The following different forms of tracks are in use on these railways:

(1) Main lines, (*a*) steel rails on iron ties of the Heindl system; (*b*) steel or steel-headed rails on wooden ties.

(2) Branch lines, (*a*) steel rails on iron ties of the Heindl system; (*b*) steel rails on wooden ties.

(3) Local lines of standard gauge, (*a*) steel rails on iron longitudinals of the "Rhenish" type; (*b*) steel rails on iron cross-ties of the Heindl system, but lighter than the ties for main lines; (*c*) steel rails with longitudinals or cross-ties, Hartwich system.

(4) Local lines of meter gauge, iron rails on iron ties of the Heindl system.

The Heindl system of track with cross-ties has now been adopted as the standard system of metal track for main lines, and it has also been applied (in a lighter form) for secondary lines. Up to the end of 1887 this track had been laid as follows:

	Miles.
1883	.17
1885	19.10
1887	35.34
1887	31
Total	85.61

The Heindl system of track for main lines is described in full further on. Two lighter forms of this track have been designed for secondary lines of standard and meter gauge: (3*b*) 8.2 feet long, 7.2 inches wide at the bottom, 2.4 inches deep, with ends 3 inches deep, top table .36 inch thick; weight, 86.83 pounds; no tie plates are used, the ends of the tie being bent up at an inclination of 1 in 20; bolted clamp fastenings on the Ruppel plan are used; (4) 5.57 feet long, 6 inches wide at the bottom, 1.72 inches deep, with ends 2.40 inches deep, top table .32 inch thick; weight of tie, 43 pounds; the rails are fastened by bolts and clamps on the Roth-and-Schuler plan (see "Baden State Railways"). The longitudinals of the Rhenish type are similar to those on the Alsace-Lorraine Railways; they are 8.8 inches wide on top, 12 inches wide at the bottom, 2.4 inches deep; at the joints were cross-ties of **T**-section, 7.5 feet long, to which the longitudinals were secured by bolted clamps holding the flanges (See plate No. 12); the outer flange rested on packing pieces so as to give the rail the inward inclination of 1 in 20; round tie-rods 1.02 inches diameter were used, spaced one to each rail length; they passed through the webs of the rails. A lighter form of this longitudinal was 29.42 feet long, 6 inches wide on top, 8.4 inches wide inside at the bottom, and 9.2 inches wide over all at the bottom; 2.4 inches deep; sides .24 inch thick, and top table .32 inch; weight, 35.21 pounds per yard. The top table had a small rib along each edge, forming a channel for the rail flange. The rails were fastened by bolted clamps similar to those used on the Hesse-Louis Railway, but the bolts had not eccentric necks. The Hartwich system of combined rail and longitudinal has been tried on a length of 6.2 miles. The rails were 24.6 feet long, 6 inches high, with a head 1.8 inches wide and a flange 4.8 inches wide; the weight was 58.35 pounds per yard. They were connected by tie-bars 1.8 inches by .36 inch, turned and screwed at the ends, passing through the webs of the rails and secured by a nut on each side of the web. The weight of the track was about 136 pounds per yard. At joints the rails rest on grooved bed plates, to which they are fastened by bolted clamps similar to those of the Hesse-Louis Railway, but without eccentric necks on the bolts.

The following is from official statements and drawings furnished in April, 1889, for the purpose of this report:

The management of the Bavarian Government railways has made experiments for a number of years with different systems of metal track, both with iron longitudinals and iron cross-ties. Based upon the experience obtained by these trials a track with iron cross-ties, on the Heindl system, has been used since 1885, in combination with wooden ties, for all new construction and in the reconstruction of main lines. This track includes a method of fastening the rails patented by Mr. Franz Heindl, chief inspector of the Austrian state railways (see "Austria"). These Bavarian lines are of standard gauge, 4 feet 8½ inches.

Of the total length of the railways, comprising 4,063 miles, there were in 1889 the following systems of track:

	Miles.
Wooden ties	3,312
Wooden longitudinals on bridges	3
Iron longitudinals	399
Iron ties, of different systems	33
Iron ties, Heindl system	107
Hartwich system and stone blocks	209
Total	4,063

The following particulars refer to the Heindl system. The ties have been laid between 1885 and 1889; the maximum grade upon which they are placed is 2½ per cent., and the minimum radius of curves 984 feet. The traffic consists of express and ordinary passenger trains and freight trains. The amount of traffic on the different lines, per yearly average, is 200 to 1,400 passengers and 2,500 to 6,500 tons of freight per day. The express engines weigh 35.43 tons each, and have a weight of 12.32 tons on the driving wheels; the maximum speed is 43½ miles per hour. The freight engines weigh 41 tons each, have a maximum load per axle of 13.8 tons, and travel at a maximum speed of 25 miles per hour.

The ballast is partly gravel and partly of broken stone. It completely fills the interior of the tie and is compressed very firmly by the pressure of passing trains.

The ties are of wrought iron, and are used without any paint or other protection against rust. They are manufactured in Bavaria by the Maximilian Works, at Haidhof, and by Krämer Brothers, of St. Ingbert. They cost, in April, 1889, $30.50 per ton at the works. So far there had not been any appreciable wear. The reasons for adopting these ties were to obtain a firm and stable track, a long life for the ties, and a security of the rail fastenings. The general results have been very satisfactory, there having been no trouble with the fastenings, nor with the maintenance of track. No breakages have occurred and the rails only break the same as on wooden ties. An iron tie costs 96 cents, and a pine tie, impregnated with chloride of zinc, 67 cents. The latter lasts on an average about twelve years.

Besides the proper shape, a certain dead weight of the tie is absolutely necessary for the stability of the track, and the engineers of these lines consider a weight of 139 pounds per tie as the minimum admissible weight for track with ordinary traffic. Mr. Heindl recommends for main lines with a heavy traffic a weight of 175 pounds per tie. [While general experience does not seem to bear out the requirement of such weight, I would call especial attention to this point of minimum weight, as in many cases metal ties have been designed and invented in which every other feature has been sacrificed in order to secure the least possible weight and amount of material and consequent cheapness in first cost. Ties of such design cannot be efficient in service, and are likely to make a track very inferior to one laid with wooden ties, however desirable the use of the metal may be in itself. This is one of the pronounced defects of some of the ties patented in this country.—E. E. R. T.]

The engineers of these lines consider the horizontal tie to be superior to one having the ends inclined upward. A tie-plate is also considered advantageous with metal track, because it distributes the vertical pressure over a larger area, prevents the flanges of the rail from wearing into the tie, and gives also a wider bearing to resist lateral pressure. Good results are expected from the method of fastening the rails, especially on account of the separation of the part resisting the horizontal thrust from the part resisting the overturning of the rail. The former are firmly seated, and are not affected by the inevitable motion of the rail. [It has the disadvantage, however, of increasing the number of parts, but this appears to be a matter of very secondary importance in European track practice.—E. E. R. T.]

The ties are of inverted trough section (See plate No. 14), 8.2 feet long, 5.2 inches wide on top, 9.6 inches wide at the bottom. They are horizontal and of uniform section throughout; the ends are closed by bending down the top table to a depth of 4.8 inches, and in the older ties the sides were also bent round at the ends. The weight is 138.6 pounds per tie. The top table is .36 inch thick, and the sides from .3 inch near the bottom to .32 inch near the top. At each rail seat are two oblong holes 2.32 inches long by .92 inch wide, 4.08 inches apart in the clear. There are eleven ties to a rail length of 29.52 feet; the joint ties are spaced 20 inches center to center, the next 30.1 inches, the next two spacings 34 inches, and the remainder 36 inches.

The rails are of steel, of flanged section, 5.22 inches high, with a flange 4.20 inches wide, head 2.32 inches wide, top table 9 inches radius, top corners .56 inch radius, weighing 62.78 pounds per yard. Each rail rests on an iron tie-plate 4.64 inches long, 5.12 inches wide, with notches for the rail fastenings; the rail seat has an inward inclination of 1 in 20, and is from .22 inch to .44 inch thick; at the outer edge the plate is .68 inch thick, having a rib which resists the outward pressure of the rail flange. The weight is 2.16 pounds per plate. The fastenings consist of gauge-washers, clamps, and bolts; the former are 2.6 inches wide along the rail, and of different lengths according to the gauge; one end butts against the tie-plate, having a notch for the bolt, and the other end has a lug which fits into the hole in the tie. Upon this is the clamp, one end resting on the washer and the other on the rail flange. They are held together by a ⊥-headed bolt, .80 inch diameter, weighing .95 pound each, with the nut screwing down on the clamps. At one tie in each rail length a short piece of angle-bar is bolted to the rail, the flange bearing against the side of the rail fastening and preventing creeping of the rail. The fastening is similar to the "Ruppel" type (see Left-Bank-of-the-Rhine Railway), but with the rail-clamp of the latter divided horizontally into two parts. The rail joints are suspended and are spliced by a pair of angle-bars and four bolts; the bolts are .88 inch diameter, and are spaced 4.20 inches center to center, for the inner ones, and 5 inches for the outer ones. A space of .20 inch is left at the rail ends.

The weight of this track per rail length is given as follows:

[Per 29.52 feet.]

Material.	Weight.	Material.	Weight.
	Pounds.		*Pounds.*
2 rails	1,235.52	44 fastening bolts	46.42
11 ties	1,524.60	44 rail-clamps	24.64
2 outer angle-bars	39.16		
2 inner angle-bars	52.36	Total	3,011.14
8 splice-bolts	10.12		
22 tie-plates	47.52	Total per yard	334.40
44 gauge-washers	30.80		

BADEN STATE RAILWAYS.—Mr. Bricka, in his report to the Minister of Public Works (France), mentioned the curious fact that on these lines the work of maintenance is done by contract; the railway administration furnishing the material. The work is said to be well done, and the method to have proved satisfactory. The plan has also been tried on the Wurtemberg State Railways, and on the Swiss Central Railway. He gives the following statement of the track for the end of 1884:

	Miles.
Main lines	701.84
Local lines	97.96
Total track	1,425.38
Wooden ties	1,239.38
Metal longitudinals	3.72
Metal ties	182.28

The following particulars are from an official statement received in September, 1889:

The total length of railways in operation is 857.888 miles, of which 343.288 miles are double track and 514.600 miles are single track. The total length of main track is 1,178.10 miles, and of this amount at the end of 1888 there were 569.878 miles, or 47.8 per cent., laid with metal track, including 2.604 miles with longitudinals and 567.274 with cross-ties. Iron cross-ties were first used in 1881, and the experience with them proved so satisfactory that they are being used exclusively for renewals for all main track now laid with wooden ties. During the last few years iron ties have also been used in the construction of new roads. The renewal of wooden with iron ties upon all the main tracks of these railways will be completed in eight or ten years.

The ties weigh 94.16 pounds each, but it is intended to use heavier ties as an experiment. They are not painted or otherwise treated, but no damage by rust has been observed. The time during which they have been in service is too short to allow of any observations being made as to their durability or life. As far as the experience goes, the iron ties are found to have considerable advantages as compared with wooden ties; they last longer, and so reduce the cost of maintenance; they also keep the track in line better and maintain the gauge more accurately. At first, however, the maintenance of track on iron ties is not cheaper than that of track on wooden ties. The adjustment of gauge is effected by a washer on the bolt, with the bolt hole placed eccentrically, allowing for each line of rails three side movements of .132, .268, and .40 inch, so that the gauge can be widened .80 inch.

The ballast is generally of coarse gravel or broken stone, in pieces upwards of 2.4 inches diameter, free from earth or sand. This material admits of proper drainage and has proved satisfactory. The heaviest locomotives weigh 107,800 pounds in working order, and have a maximum load of 15,400 pounds per driving-wheel. The traffic consists of passenger and freight trains.

The ties are of the original "Berg-and-Mark" type, as used on the Elberfeld division of the Prussian State Railways (see Plate No. 12); formerly they were of iron, but since 1883 they have been made of mild steel. The earlier ones were 7.38 feet long, which was considered too short. The ties now used are 7.87 feet long, 4.8 inches wide on top, 8.8 inches wide at the bottom, 2.4 inches deep, with the sides vertical for 1.2 inches from the bottom. The thickness of the sides is from .24 to .28 inch, and of the top table .36 inch. The middle part of the tie is horizontal for a length of 3.28 feet. The rail seats are inclined upward 1 in 20 for a length of 25 inches, and then the tie inclines downward to the end. At the ends the top table is bent down and flared out, so that the closed ends are 4 inches deep and 10.8 inches wide over the bottom. The bolt holes are .84 inch square, with rounded corners. They are staggered at each rail seat instead of being placed opposite one another. The rails are of flange section, made of Bessemer steel. The fastenings consist of bolted clamps, on the Roth-and-Schuler plan. (See plate No. 13.) The bolt is .76 inch diameter, with a neck .80 inch square, and a round cup head 1.36 inches diameter; the bolt passes through a gauge-washer and rail clamp, and the nut screws down on the latter. The washer is 1.76 inches square and .56 inch thick; it has a bolt hole .80 inch in diameter, so placed as to be .28, .412, .548, and .68-inch from the four sides, thus permitting a close adjustment to gauge; the rail flange buts against this plate or washer. The clamp is of channel shape (┌──┐) and fits over the gauge washer; it is 2.84 inches by 2.6 inches, with an oval bolt hole .84 by 1.24 inches; it is about .52 inch thick; the shorter leg is .68 inch deep and bears on the rail flange; the longer one is 1.16 inches deep and bears on the tie. There are 11 ties to a rail length of 29.52 feet; the joint ties are spaced 22.8 inches apart, center to center, and the intermediate ties 33.72 inches. The weight of this track is 2,640 pounds per rail length, or 267.6 pounds per yard. Prices bid for ties in December, 1889, averaged about $38.20 per ton.

The road-bed is crowned at subgrade, and the ballast is filled in level with the tops of the ties. For double track lines the width over the bottom of the ballast is 26.24 feet, and the side slopes are 2 to 3, giving 18 inches of ballast beyond the ends of the tie; the depth of ballast is 18 inches at the side, and 12 inches at the middle. For single track the width at the bottom is 14.27 feet, side slopes 2 to 3, giving 18 inches of ballast beyond the ends of the tie; the depth of the ballast is 16 inches at the side and 12.8 inches at the middle. At stations the top of the ballast is level with the surface of the ground; it is 11.48 feet wide on top, 10 inches deep at the sides, and 16 inches deep at the middle, so that all water runs to the bottom at the middle, where there is a drain covered with broken stone of large size.

WURTEMBERG STATE RAILWAYS.—Metal cross-ties have been used since 1879, and several different forms have been used. Those now used are of the modified Vautherin section, with ribs instead of flanges on the lower edges, and with a rib 1.66 inches wide along the underside of the top table to strengthen it at the holes for the fastenings. The tie is 7.87 feet long, 5.2 inches wide on top, 10.4 inches wide at the bottom, 3.2 inches deep; the top table is .36 inch thick, and .52 inch at the thickened part. The weight is 130 pounds per tie. The tie is bent up at the rail seat, and then slopes down so that the end is at the same level as the middle. The ends are closed by riveted pieces. The rails are secured by gib and cotter fastenings, similar to those used on the Elberfeld division of the Prussian state railways, and they have given satisfaction. The work of maintenance is less than with track on wooden ties owing to the weight of the tie. At the end of 1884 there were 194 miles of metal ties, out of a total of 1,426 miles, and it was then expected to extend this about 37.2 miles per year.

The following is Mr. Bricka's statement of the track for the end of 1884:

	Miles.
Main lines	878.54
Local lines	78.74
Total track	1,404.92
Wooden ties	1,185.44
Metal longitudinals	16.74
Metal ties	194.06
Stone blocks, etc	8.68

ALSACE-LORRAINE STATE RAILWAYS.—A number of different systems of metal track have been tried, and in August, 1889, the management reported that there were in use eight kinds of metal track and four systems of attachments. Of the total length of track there were then as follows:

	Miles.
Wooden ties	888.931
Metal longitudinals	583.686
Iron and steel ties	312.015

The form of cross-tie adopted in 1887 is of the modified "Berg-and-Mark" type (See plate No. 12); 8.85 feet long, 5.2 inches wide on top, 10.52 inches wide over all, 3.6 inches deep; the sides are .28 inch thick and the top table .32 inch; weight 156½ pounds. The earlier form of the tie of this type was 7.87 feet long, 4.4 inches wide on top, 7.84 inches wide inside at the bottom, 9.2 inches wide over the ribs, 3 inches deep, top table .4 inch thick, weight 126.5 pounds; it was bent to a curve to give the rails an inward inclination. The rails were of flange section and were secured by clamps and bolts on a plan similar to the Ruppel plan. The newer ties are horizontal, and the "Haarmann" tie-plate and bolt fastening are used, as on the Cologne division of the Prussian State Railways. The ends are closed. With this newer form of track there are ten ties to a rail length of 29.52 feet; the joint ties are spaced 23.6 inches, center to center, the next 30.4 inches, the next 38 inches, and the intermediate ties 30⅝ inches. The weight of the track is 3,204.88 pounds per rail length, or 325.70 pounds per yard. The Hœrde or Post ties are also being tried.

A cross-tie of the "Haarmann" type has also been used; it was 7.87 feet long, 4.28 inches wide inside at the bottom, 10 inches wide over all; the edges of the flanges were turned down .80 inch; depth over all (not including the end plates) 2.56 inches. The end plates were of double angle, or ⌐┘ section, riveted to the horizontal flanges, closing the end of the "cap" of the tie and projecting 1.2 inches below the flanges. The weight was 106.7 pounds per tie. The "Haarmann" tie-plate and rail fastening were used, requiring only one bolt and clamp for each rail.

The Hilf system of longitudinals has been tried on this line. The longitudinals were 24.6 feet long, 12 inches wide at the bottom and 2.4 inches deep; the thickness of sides and top was .32 inch. The rails were secured by bolted clamps, on a plan similar to that used for the cross-ties on the Hesse-Louis Railway, but the bolts had not eccentric necks. The rail joints were spliced by one angle-bar and one channel-bar. At the joints of the longitudinals was a cross-tie 7.5 feet long, and the gauge was maintained by tie-rods passing through the web of the rail and secured by nuts; these were spaced 12.3 feet apart. Longitudinals of the "Rhenish" type were also used; they were 8 inches wide on top, 12 inches wide over the bottom ribs, 9.84 inches wide inside at the bottom; 3.6 inches deep; thickness of sides .32 inch, and of top, .36 inch. They were 24.6 feet long, and weighed 63.6 pounds per yard, a little more than those of the "Hilf" type. The ends were closed. The joints of the longitudinals were spliced by saddle plates 28.8 inches long, of almost similar section to them, fitting inside and secured by bolts. There were no cross-ties, the gauge being maintained by tie-rods placed at intervals of 12.3 feet. Longitudinals are now only used in exceptional cases. The Hartwich system of combined rails and longitudinals, consisting merely of deep flange rails, without cross-ties, has been used where local lines are laid in the streets or along roads. The rails were 29.52 feet long, 7.2 inches high, with a head 2 inches wide and a flange 4.8 inches wide; weight, 73.2 pounds per yard. They were connected at intervals of 9 feet 10½ inches by round tie-rods, 1 inch diameter, passed through the webs and secured by a nut on each side of each rail; there were three tie-rods to each rail length. The rails were spliced at the joints by angle-bars with two rows of bolts. The weight of the track was 1,647.9 pounds per rail length, or 183.10 pounds per yard. Great care was taken to insure proper drainage. At subgrade a line of large rough stone blocks was laid under each rail, and upon this was a bed of broken stone in which the rail was bedded to the middle of the web. The ballast was filled in to the level of the rail heads, with a paving of blocks just under the tie-rods. Cross-drains were laid at intervals. These precautions, however, were expensive, diminishing any economy due to this system of track. This track was first laid about five years ago.

The weights of the engines in use in 1885 were as follows:

Class of engine.	Total weight.	Maximum weight on one axle.
	Pounds.	*Pounds.*
Passenger	80, 000	32, 230
Freight	86, 240	30, 140
Mixed	68, 750	28, 600
For secondary lines	55, 880	....

The following is Mr. Bricka's statement of the track for the end of 1884:

	Miles.
Main lines	699.98
Local lines	109.12
Total track	1,516.52
Wooden ties	874.82
Metal ties	79.98
Metal longitudinals	559.86
Stone blocks, etc	1.86

MAIN-NECKAR RAILWAY (See plates Nos. 12 and 13).—On this line mild steel cross-ties have been used since 1880, and their use is being extended. The original Vautherin section is adhered to, with the rail-seats formed on the Hosch-Lichthammer plan. Mr. Bricka in his report (1885) stated that wooden ties were not being used for new lines or general renewals. He reported the track as excellent. He examined ties that had been in service for three years and found no signs of wear under the rails or at the bolt-holes. The track behaved as well under the passage of trains as the best track on wooden ties, and cost less for maintenance. The following is his statement of the track for the end of 1884:

	Miles.
Main lines	58.28
Total track	148.94
Wooden ties	126.48
Metal ties	20.46

In October, 1889, I received the following report from this railway, with a letter stating that it would have been sent at an earlier date, but that having adopted that year a heavier section of tie they preferred to wait until particulars of these new ties could be given:

Up to the end of 1889, about 100,000 cross-ties on the Hosch-Lichthammer plan had been laid; equal to about 12,500 rail lengths of 24.6 feet, or 58.125 miles of track. Iron ties were first used in 1881, and each year, until now, 10,000 ties have been laid; in 1884 and 1885, however, 20,000 ties were laid each year. The ties are now of mild steel. The traffic is very heavy. The ties are manufactured by the Hosch Iron and Steel Works, of Dortmund; the De Wendel Works, of Haizengen; and the Hoerde Mining and Rolling Mill Company, of Hoerde. The cost per ton (1,000 kilograms = 2,200 pounds) is from $33.10 to $35.90, delivered at the Darmstadt station. At present the life of the ties cannot be given, but it is estimated (from eight years' experience) that they will certainly last between thirty and fifty years. Formerly gravel ballast was used, but broken stone is now adopted as experience has proved its superiority, especially for the heavy ties of the section of 1889. The change from wooden to iron ties was made because at the same cost of iron and wooden ties the former give certainly more security and better gauge, and are also of longer duration. At first ties of .3[illegible] inch thickness were used, which, at the prices at that time, were hardly more expensive than oak ties. These light ties (weighing 84.414 pounds each) had the disadvantage that the entire track, rails and ties, was too light; it had to be frequently tamped and straightened or lined up. It was thought that this objection would be remedied by increasing the thickness of the tie to .40 inch, giving a weight of 106.75 pounds. The result was not as good as had been expected, and therefore, in

1889, ties weighing 135.3 pounds were adopted, but were not delivered until October of that year. The good results expected from the use of metal ties have been in the main realized, and the safety of the traffic is increased. The maintenance of track with the light metal ties was a little more expensive than with wooden ties. There is no more trouble with the rail joints on these ties than on wooden ties. Breakages of ties occur very rarely, and of rails hardly ever. The metal ties have maintained the gauge accurately, which was not always the case with wooden ties. Formerly two-thirds of pine and one-third of oak ties were used, both impregnated with a solution of sublimate. They were 8.2 feet long, 5 to 5.5 inches wide, and 4 inches thick. The cost was $1.27½ per tie for oak, and 73¾ cents for pine. The adzing of the rail seat cost 2 cents, and the preserving 8¾ cents, so that the cost for tie complete was $1.38¼ for oak and 84½ cents for pine. The life is from fifteen to twenty years for oak, and from five to eight years for pine. The sharpest curve on which the metal ties are laid is of 1,148 feet radius, and the steepest grade is 1 in 333.

The ties of 1880 were of mild steel; they were 8.2 feet long, 4 inches wide on top, 2.4 inches deep, 8.8 inches wide over the bottom flanges, which were .6 inch wide; the thickness was from .24 inch at the lower part of the sides, to .32 inch at the top table. The middle portion of the tie was horizontal for 4.26 feet, the rail seats were inclined 1 in 20 for 8.52 inches, and the tie was then horizontal to the end. The weight was 81.41 pounds per tie. The fastenings were of the Ruppel plan of bolted clamps. The bolt holes at each rail seat were staggered. The rail joints were even and suspended, spliced by straight plates and four bolts. To a rail length of 24.6 feet there were nine ties; the joint ties spaced 21.6 inches apart, center to center, and the intermediate ties 34.8 inches. The ties of 1883 were similar to the above, but the thickness was from .26 inch to .36 inch. The ends and middle of the tie were in the same horizontal line, the rail seats being inclined and then sloped back to the normal level. At the rail joints one of each pair of clamps was long enough to cover the width of the flange of the rail. There were nine ties to a rail length of 24.6 feet; the joint ties were spaced 20.4 inches apart, center to center; the next 31.88 inches, and the intermediate ties 36 inches. The weight was 91.85 pounds per tie. These ties were of mild steel. The ties of 1886 were similar to those of 1883, but the thickness was from .32 inch to .40-inch. The rail joints were spliced by one channel bar and one straight bar, 27.2 inches long, with six bolts. The weight was 106.75 pounds. There were nine ties to a rail length of 24.6 feet; the joint ties spaced 26.08 inches center to center, the next ones 29.04 inches, and the intermediate ties 36 inches.

The ties of the type adopted in 1889 are of the same general type. They are 8.2 feet long, 5.6 inches wide on top, 2.8 inches deep, 10.4 inches wide over the bottom flanges, which are .72 inch wide. The thickness is .32 inch at the sides and .40-inch at the flanges and the top table. The rail seat is inclined for a length of 10 inches, and then slopes back in 6 inches to the horizontal line of the tie. The ends are bent to a depth of 4.8 inches. The weight is 135.2 pounds per tie. The fastenings are of the Ruppel system. The rails are of flange section, 5.2 inches high, with a flange 4 inches wide. The joints are spliced by one straight and one channel bar, with six bolts. For a rail length of 24.6 feet there are nine ties. The joint ties are spaced 26.08 inches center to center, the next ones 29.04 inches, and the intermediate ties 36 inches. For a rail length of 32.8 feet, there are twelve ties; the joint ties are spaced 26.08 inches center to center, the next ones 28.64 inches, and the intermediate ties 35.2 inches. The weight of the track for a rail length of 24.6 feet is 2,337.32 pounds, or 28.5 pounds per yard.

HESSE LOUIS RAILWAY.—On this line the Hilf system of longitudinals has been tried, but this system of track was abandoned, as the cost of maintenance on the 78 miles laid with it was found to be, during the years 1881 to 1886, 36 per cent. higher than that of track on cross-ties, The "Berg-and-Mark" type of cross-ties is now used. The following is Mr. Bricka's statement of the track at the end of 1884:

	Miles.
Main lines	420.36
Total track	757.02
Wooden ties	484.46
Metal longitudinals	78.12
Metal ties	192.20
Stone blocks, etc	1.24

The following is from a special report received in January 1890:

Metal track is in use to a greater or less extent on all the divisions of the road. The lines from Frankfort-on-Main to Eschhofen, from Wiesbaden to Niedernhausen, from Babenhausen to Hanau, and from Erbach to Eberbach, are laid entirely with metal track. At the end of 1888, there were 304.42 miles of main line, and 75.02 miles of local lines, laid with such track; making a total of 379.44 miles. The steepest grade on which the track is laid is 1.43 per cent. (1 in 70), and the sharpest curve has a radius of about 984 feet. The first metal track was laid in 1874. The traffic consists of passenger, freight and express trains. The heaviest locomotives weigh 48 tons, without the tender, and have a maximum load of 7 tons on the driving wheels.

At the end of 1888 the metal track included 300.08 miles of cross-ties and 79.36 miles of longitudinals. The longitudinals are of the Hilf type, with middle rib. The cross-ties are of similar section, but without the middle rib; they are 8.2 feet long and weigh 114.4 pounds. Both longitudinals and cross-ties are of rolled iron. They are not treated with any preparation to resist rust. They are manufactured by the Luxemburg Metal Works, the Saarbruck Iron Works, and the Burbach Forge Company, near Saarbruck. During 1888, the contract price for cross-ties averaged $28 per 2,200 pounds, at the works. Longitudinals have not been purchased since 1879. The cost of maintenance of the track on metal ties can only be given for the parts which are laid entirely with metal track; on the other parts the costs for wages, road-bed material, etc., for track on iron and wooden ties, are not kept in separate accounts. In 1888 the cost for maintenance of track, for material and wages, per kilometer, was as follows:

(*a*) Frankfurt Station to Eschhofen	$108
(*b*) Wiesbaden to Niedernhausen	79
(*c*) Babenhausen to Hanau	87
(*d*) Erbach to Eberbach	85

The cost per car axle per kilometer is calculated as follows: (*a*) 6.25 cents; (*b*) 8.5 cents; (*c*) 7.25 cents; (*d*) 9.75 cents.

At curves, the holes in the longitudinals are drilled to correspond to the curves, and the gauge is kept by the cross connections and the cross-ties under the joints of the longitudinals. With cross-ties, the bolts which fasten the rails have eccentric necks which admit of an adjustment or widening of gauge at curves of .72 inch in nine movements. Tie-rods are used with the track on longitudinals. When first laid, only one tie-rod was placed to each pair of longitudinals, but experience proved that a second was desirable. These tie-rods are placed at the middle and ends of the rails, and are secured by bolts and nuts. As to the durability, the time during which the metal track has been in service to a large extent is too short to enable a definite statement to be made. The ballast consists of gravel and broken stone. Coarse gravel or broken stone are good; fine gravel or sand are not so satisfactory. The width of ballast is from 11.48 feet to 22.96 feet. The rails are of flange section; those on longitudinals weigh about 52 pounds per yard; those on cross-ties weigh 71.65 pounds per yard. In exceptional cases, rails weighing 71.65 pounds per yard will be laid on longitudinals. On longitudinals the rail joints are spliced by a pair of plain splice bars; on cross-ties they are spliced by a pair of angle-bars. On track with cross-ties the rail joints are suspended. Metal track was used principally because wooden ties were sometimes difficult to obtain, and also because with metal track a better track-laying and maintenance of gauge is insured than is attainable with wooden ties. The results with metal track thus far are thoroughly satisfactory. With good road-bed material the maintenance of the track gives no trouble, and neither is there any trouble with the rail fastenings. No transverse breakages have occurred with longitudinals or cross-ties; on the other hand cracks lengthwise of the tie are not uncommon between the bolt holes, and a stronger construction of the track was very soon required. An opinion can not yet be given as to the comparative durability or life of metal and wooden ties. An impregnated pine tie costs at present 86 cents; an impregnated beech tie, 84 cents to $1.27; and an oak tie, $1.30 to $1.42. The life of an impregnated pine tie averages ten years, that of an impregnated oak tie, twelve years. The life of beech ties is not yet determined. The temperature ranges between — 15° C. and + 25° C. in the shade. No effect of the climate upon wooden or metal ties has been observed. The cross-ties are considered better than longitudinals, as they give a better drainage of the road-bed, and consequently the work of maintenance of the track is less.

The following particulars are taken from the drawings accompanying the above communication:

The longitudinals are 29.39 feet long, for rails 29.52 feet long; the joints of rails and longitudinals corresponding. They are 7.2 inches wide on top, 12 inches wide at the bottom, 2.4 inches deep; the sides are vertical for 1.2 inches from the bottom and the middle rib is the full depth. The thickness is .32 inch; the middle rib is .8 inch thick at the upper part and .4 inch thick at the bottom. The cross-ties at the joints are of similar section; they are 8.53 feet long, with the middle portion horizontal and the ends bent up at an inclination of 1 in 20 to give an inward inclination to the longitudinals and rails. Each rail is secured to the longitudinal by twelve pairs of bolted clamps, spaced about 34 inches center to center, and 26.2 inches at the rail ends. The longitudinals are attached to the cross-ties by bolted clamps. The longitudinals and cross-ties weigh 59.1 pounds per yard, or 579 and 168 pounds each, respectively. The weight of the track is 2,484.5 pounds per length of 29.39 feet, or 276 pounds per yard. The ballast consists of a bottom course of large stone, and an upper course of ordinary broken stone, filled in to the tops of the longitudinals.

The cross-ties are 8.2 feet long, 4.8 inches wide on top, 9.6 inches wide at the bottom, 2.8 inches deep; the sides are vertical for 1.2 inches from the bottom. The thickness of the sides is from .24 to .36 inch; the top table is .4 inch thick. The middle portion of the tie is horizontal, the rail-seats are inclined for a length of 16 inches, and the tie is then horizontal to the ends, which are closed by bending down the top table to a depth of 4 inches. The bolt-holes are oblong, 1.24 by .88 inch; they are 3.6 inches apart in the clear and are staggered, being 1.6 inches center to center. The rails are secured by bolted clamps (See plate No. 13). The bolts have eccentric necks to permit of adjustments of gauge, and have hemispherical heads, so that they can not be put in from above. The clamps are of ┏ shape, the horizontal leg resting on the rail-flange and the vertical leg on the tie. There are eleven ties to a rail length of 29.52 feet; they are spaced 25.2 inches center to center at the joints, 31.4 inches next, and the intermediate ties 34 inches center to center. The rail-joints are spliced by angle-bars and four bolts; the bars bear against the clamps on the cross-ties, and creeping of the rails is thus prevented.

LOWER PALATINE (PFALZ) RAILWAY.—The following particulars are taken from a statement and drawings furnished in September, 1889, by the officers of the Pfalz Railway (Rhenish Bavaria) for the purpose of this report;

On the railways of the Palatine, iron cross-ties have been used since 1885; at first they were of wrought iron, but are now of mild steel, manufactured by the Thomas process. As far as experience goes, these ties have proved successful. They are now used not only in continuous stretches, but also singly in exchange for wooden ties in ordinary renewals. The total quantity, up to the end of 1889, is about 160,000 ties, and there are continuous stretches of track 63.86 miles long laid with them.

The ties are of the Hoerde type, similar to the "Post" type (See "Holland"), except that each side is in one plane instead of two, as in the latter. They are 7.87 feet long, and weigh 114.4 pounds. The top is horizontal at the middle, inclined upward 1 in 20 at the rail-seats, and then sloped down to the ends, which are closed. At the outer part of the rail-seat the tie is 4 inches wide on top, 9.4 inches wide over the bottom ribs, 3.56 inches deep, .44 inch thick on top; under the rail it is 4.4 inches wide on top, 9.4 inches wide over the bottom ribs, 3.26 inches deep, .44 inch thick on top; at the inner part of the rail-seat it is 4.8 inches wide on top, 9.4 inches wide over the bottom ribs, 2.8 inches deep, .28 inch thick on top; at the middle, it is of ∩ section, flat for about 1 inch on top, 3 inches wide just below the top, 4½ inches wide over the bottom, 5 inches deep, .28 inch thick. The top table is bent down at the end, projecting 2.8 inches below the bottom of the tie. The rails are fastened by bolted clamps, on the Ruppel system. The rails are of flange section, 5.36 inches high and 4.20 inches wide over the flange. There are nine ties to a rail length of 24.6 feet; the joint-ties are spaced about 22 inches center to center, the next 33 inches, and the intermediate ties 37.75 inches. The track weighs about 2,362 pounds per rail length, or 270 pounds per yard.

LUBECK AND BUCHEN RAILWAY.—On this line metal ties have been tried since 1878. Mild steel cross-ties of inverted trough section are now used; they are somewhat narrower and deeper at the middle than at the ends. The section at the rail-seat resembles that of the Hilf or the modified "Berg-and-Mark" ties, but the vertical part of the sides is very shallow, and has a small rib on the bottom edge; the section at the middle more nearly resembles that of the "Post" tie, but here too the change of plane of the sides is very low down. The tie is 7.87 feet long, and weighs 107.8 pounds; at the rail-seat it is 9.2 inches wide over the bottom and 3.2 inches deep, with the top table .36 inch thick, and the sides .3 inch thick at the top and .25 inch at the bottom; at the middle it is 8 inches wide at the bottom and 4 inches deep, with the same thickness. The rails are of flange section, weighing 70.42 pounds per yard, and are secured by clamps and ⊥-headed bolts; the bolt-holes are staggered. For a rail length of 29.52 feet there are eleven ties; the joint-ties are spaced 27.12 inches center to center, the next ones 33.24 inches, and the intermediate ties 33.32 inches. The weight of the track is 2,716.36 pounds per rail length, or 276 pounds per yard.

HALBERSTADT AND BLANKENBERG RAILWAY.—Cross-ties of the "Berg-and-Mark" type are used, with gib and cotter fastenings. They are 7.12 feet long, have the ends bent to an inclination of 1 in 20, and weigh 88 pounds each. The rails are of flange section, 21.62 feet long, 5.2 inches high, with a flange 4 inches wide. The weight of the track is 1,767.87 pounds per rail length, or 245.37 pounds per yard. This railway includes the rack-rail line, on the Abt system, from Blankenberg to Tanne. The ties are of similar section to the above, 7.21 feet long, 8 inches wide on the bottom, and weighing 90 pounds each. The ends are closed by riveted angle-irons, and other angle-irons are riveted inside at about 18 inches from the end. The ties are spaced about 35 inches center to center. The rack-rail is carried in chairs which are fastened to the ties by gib and cotter fastenings similar to those for the track-rails. The ballast is filled into the ends of the tie to the inner angle-irons, and the middle part of the track between the rails is left entirely clear of ballast.

MULHAUSEN, ENSISHEIM AND WITTENHEIM RAILWAY.—This is a country tramway line, built partly along the public highway, and the information given, which is taken from a report published in 1888, refers only to the section from Mulhausen to Ensisheim, the extension of 4.83 miles to Wittenheim not having been built at the time of the report. The line was opened in December, 1885, being built to develop the trade of the old city of Ensisheim, which had declined on account of its isolation from railway communication. The line is 10.22 miles long, 1 meter gauge; maximum grade 2.4 per cent. for 295.20 feet, with other grades of 1.2 to 2 per cent. for a total length of 1,459.60 feet. The sharpest curve is 65.6 feet radius, and the alignment is as follows: Tangents, 7.70 miles, or 76 per cent.; curves of 3,280 feet radius, .35 mile, or 3 per cent.; curves of 1,640 to 328 feet radius, 1.63 miles, or 16 per cent.; curves of less than 328 feet radius, .53 mile, or 5 per cent.

Three systems of track have been adopted: (1) The Demerbe track, consisting of a rail of saddle or inverted trough section, weighing 61.36 pounds per yard. On the upper surface is a groove for the wheel flanges. It is used for a length of 3.5 miles for passing through villages It requires no bolts, being secured by keys. On tangents the rails are 29.52 feet long, and on curves of 65.6, 98.4, and 114.8 feet radius they are 14.76 feet long, with two cross-ties. The rail is the same as that used on the Mulhausen street railway, but the attachments and splices are simpler. (2) Flange rails on oak ties. (3) Flange rails on iron longitudinals. This system, employed especially where the width of the road is not more than 22.96 inches from the center of the track to the side, is composed of a rail 3.4 inches high, bolted to an iron longitudinal. The joints are entirely suspended, the splice plates being clear of the ends of the longitudinals. The rails weigh 31.69 pounds per yard, the longitudinals 24.75 pounds per yard, and the track complete about 120.75 pounds per yard. The rails are 29.35 and 29.52 feet long, and the longitudinals 27.71 and 27.88 feet. The gauge is maintained by five tie-rods of round iron to each pair of longitudinals, secured by nuts at the ends; they are spaced 5.9 feet center to center. With this system of track, which is laid for a length of 2.32 miles, the minimum curvature possible is 328 feet radius, on account of the necessity of bending the longitudinals. For curves of 328 to 656 feet radius, the outer and inner rails are 19.68 and 19.51 feet long respectively, and the outer and inner longitudinals are 18.04 and 17.87 feet long respectively.

HOLLENTHAL RAILWAY.—This is a standard gauge railway between Freiburg and Neustadt, which was opened in May, 1887. It is 21¾ miles long, of which 4¾ miles are fitted as a rack railway. The rack used is of the Marsh (or so-called Riggenback) ladder type. The track is laid with mild steel cross-ties of the Hilf type, with closed ends. The rails are of flange section, and are fastened to the tie by bolted clamps; the chairs for the rack rail are bolted to the middle of the tie. The rails are 29.52 feet long and weigh 72.84 pounds per yard. There are ten ties to a rail length. The ordinary track weighs 246.3 pounds per yard, and the rack and appurtenances 256.8 pounds per yard.

TIES.

The Hoerde Tie.—This is practically the same as the "Post" steel cross-tie, already described (see Holland). In February, 1888, the manufacturing company (Hoerder, Bergwerks und Hutten Verein) stated that the following numbers of these ties had already been supplied: German railways, 500,000; Gotthard Railway, 160,000; Swiss Western Railway, 160,000; Sumatra Railway, 80,000; Dutch State railways, 100,000; total 1,000,000 ties. Besides these, about 200,000 had been laid in France and Belgium. The price then varied from $25.84 to $28.34 per ton, free on board at Antwerp, according to size and quantity.

The special features of this form of tie are that the inclination of 1 in 20 is given to the rail seat in the process of rolling, while at the same time an increased thickness is given to the same part to increase its strength and durability. The tie is also made narrower and deeper at the middle than at the ends. By the method of rolling just mentioned the metal is subjected to less working and fatigue than when the seat is stamped to shape by a subsequent operation; the thickness may be increased .12 to .16 inch, while at the same time it may be reduced at other parts of the tie without diminishing the efficiency of the tie. A reduction of 10 per cent. in weight is claimed, with equal strength and durability to a tie of uniform section. By making the tie deep at the middle its stiffness or rigidity is increased, and any buckling or bending which might alter the width of the gauge is prevented, even when the tie is improperly ballasted. For main lines it is not advisable to reduce the weight below 110 pounds, but it is claimed that for secondary railways the ties may weigh only 72.6 to 77 pounds where now ties weighing 99 pounds are used. The deepening at the middle also prevents firm tamping of the tie in the middle,.and the trackmen are given special instructions to tamp only the part under the rails, leaving the middle free, to prevent "hogging" of the ties. Such motion as the tie may have in the ballast tends to drive the ballast from the middle toward the rail seats.

For main lines the tie is 8.53 feet long, 11.2 inches wide at the ends, 9.4 inches wide for about 26 inches from the ends, and then narrowing to 4.72 inches at the middle. The depth is 5.24 inches at the middle, 2.32 and 2.92 inches at the inner and outer parts of the rail seat; the ends are closed by bending down the top table to below the level of the body of the tie. On each of the bottom edges is a broad rib of triangular section. The section is generally polygonal, each of the sides being in two planes; in some cases the sides are in one plane only, forming an ordinary inverted trough. The thickness at the rail seat is .24 inch at the bottom of the sides, increasing to .34 inch at the upper part of the sides and .36 inch at the top table. The thickness at other parts of the tie averages .24 inch. The fastenings consist of tee-headed bolts with eccentric necks, which admit of adjustment of the gauge; the bolt passes through a clamp, one end of which rests on the rail flange and the other end on the tie, the latter having a rib on the under side to bring the top level; the nut is screwed down on the clamp. The clamps are 2.6 by 2.16 inches, about .4 inch thick, and .8 inch deep at the outer side; the bolt-hole is .96 inch diameter. Special bolts, with necks of different dimensions, are used for curves, and these bolts are marked as already described for the "Post" tie (See "Holland"). The widening of gauge of .32 inch and .4 inch, required in ordinary service, can be effected with the ordinary bolts, the special bolts being used at the points of change from one adjustment of gauge to the other, and at the ends of curves of less than 3,280 feet radius. The bolt-holes are in identically the same position on all the ties. Verona nut-locks are used for the fastening and joint bolts. The rail joints are suspended and are spliced with angle-bars. For rail lengths of 29.52 feet, the joint-ties are spaced 26.8 inches center to center, and the intermediate ties about 37 inches. The weight of the track is given as follows:

Materials.	Unit weight.	Total weight.
	Pounds.	*Pounds.*
2 rails, 29.52 feet long........per yard..	67.2	1,322.64
10 ties, 8.52 feet long, 9.4 inches wide........each..	110	1,100.00
4 splice-bars, 22.8 inches long........do...	25.30	101.20
8 splice-bolts, .88 inch diameter........do...	1.21	9.68
40 rail-clamps........do..	.66	26.40
40 track-bolts, .88 inch diameter........do...	1.10	44.00
48 nut-locks........do...	.039	1.89
Weight per rail length........	....	2,605.81
Weight per yard........	....	264.825

The manufacturers give particulars of tests of the comparative strength of these types of ties: No. 1, Netherlands State Railways, narrow and deep at the middle; 8.52 feet long, 9.4 inches wide, and 2.32 inches deep at rail seats, 4.72 inches wide, and 5.24 inches deep at the middle, .24 to .36 inch thick, weighing 110 to 120 pounds. No. 2, of similar type, but of uniform section throughout, 9.4 inches wide at the bottom and 2.32 inches deep. No. 3, a tie of inverted trough section, used on the Right-Bank-of-the-Rhine Railway, Germany; 8.85 feet long, 4.8 inches wide on top, 9.44 inches wide at the bottom, 3.1 inches deep, with the inner part of the side vertical for 1 inch from the bottom, the outer part being a thickened rib; sides .28 inch and top .32 inch wide; weight 125.4 pounds. The ties were supported at the middle. A beam or rail was laid across the two track rails, and upon this heavy frogs were placed, the load being uniformly distributed. The bending down of the unsupported ends of the ties would widen the gauge. No. 1, the widening of the gauge was from .18 inch with 6,050 pounds to .39 inch with 12,100 pounds load. The only permanent set was with this last load. No. 2, with a load of 7,260 pounds, the tie failed at the middle, being entirely deformed. No. 3, the tie failed at the middle under a load of 9,680 pounds and was entirely deformed.

For light or portable railways of 24 inches gauge, the works manufacture two forms of ties: No. 1 is 32.8 inches long, horizontal and shallow at the ends, with the top table arched up at the middle to increase the depth and stiffness; the ends are closed. It is 4 inches wide and 1 inch deep at the ends, 2.24 inches wide, and 2.2 inches deep at the middle; thickness, .16 and .24 inch at the rail seats. No. 2 is of uniform section throughout. The rails are 6.56 feet long, of flange section, but with a narrower flange on the inner side of the rail; they are 2.6 inches high, 1.88 inches wide over the flange, with a head .92 inch wide. The fastenings consist of hook-bolts, the hook-head holding the rail flange and the nut being on the inside of the tie. The rail joints are spliced by straight plates riveted to one end of each rail of each section of track, the ends of the rails of the next section being inserted between the projecting plates. The ties are spaced 16 inches apart, center to center, at the joints, and 32 inches apart intermediate. The track is made in sections 6.56 feet long, each consisting of two rails, three ties, and four plates. The weight of one such section is about 88 pounds.

The Good Hope Works ties.—The Good-Hope Works, at Oberhausen, manufacture a number of different forms of ties and fastenings. One type is somewhat similar to that adopted for the Indian State railways. (See "India.") It is 8 feet long for standard gauge lines; at the middle it is 4½ inches deep and 8½ inches wide on the bottom; at the rail seat it is 9½ inches wide on the bottom, with vertical sides and rounded corners; the top table is horizontal and at the ends it is bent down and flared out to a width of 13 inches. The rails are of flange section and rest on metal tie-plates, which give them the required inclination. The fastenings consist of a gib to hold the outer flange and two gibs and a cotter for the inner flange. The plate from which the tie is made is 8 feet 5 inches long by 15¼ inches wide, and weighs 9 pounds per square foot. The tie weighs 98 pounds, the two tie-plates weigh 12 pounds, and the fastenings 9½ pounds, making a total of 119½ pounds for each tie complete. Similar ties are made for gauges of 5 feet 3 inches (weighing 125½ pounds) and 5 feet 6 inches (total weight 128½ pounds). It is also made for the 3 feet 6 inches gauge, but is of arched section in the middle, and broader and shallower under the rails; the tie-plates are not used; the tie weighs 56 pounds, or 8 pounds per square foot, and the fastenings 3½ pounds. The rails are of flange section, weighing 41½ pounds for the narrow gauge and 53 pounds per yard for the wider gauges. Ties of the Haarmann and Vautherin types are also manufactured.

The Burkhardt longitudinals.—The following description of this system of track is abstracted from the Minutes of the Proceedings of the Institution of Civil Engineers (England), Vol. LXXXI, 1885:

"The longitudinal is of inverted channel section, 27 feet 10½ inches long, 9.76 inches wide on top, 2.36 inches deep, and 12.6 inches wide over the flanges. One of the ends is closed by a riveted plate and the other by the cross-tie connection. A space of 19½ inches is left between the ends of the longitudinals, and this space comes under the rail-joints. The rails are fastened at nine points by bolts and clamps. There are three cross-ties to each longitudinal; they are of angle or channel iron, 6 feet 7 inches long, 4 inches deep. The weight of the track is 268 pounds per yard."

Ties made from old rails.—A system has been designed by L. Schulke, of Dusseldorf, for utilizing old rails for ties. The rails, of flange section, are cut into lengths of about 7 feet 6 inches, and two of these pieces laid on the side, head to head, form one cross-tie. The heads and webs are cut away on the upper side at each rail seat for the metal tie-plates, upon which the rails rest. The track rails are secured by bolted clamps, different sizes of clamps being used for the adjustment of the gauge. It is stated that the average price for old rails in Germany in 1887 was about $10 per net ton for heavy iron rails and about $7.50 per ton for light steel rails. The weight of these ties is from 60 to 100 per cent. greater than that of wooden ties. It is claimed that while ten iron or wooden ties are used to a rail length of 29.52 feet, only eight of these ties would be required, especially if the two parts of each tie were placed further apart, and the tie plates lengthened accordingly. They may be spaced from 29.6 inches at the joints to 36 inches intermediate. The manufacture requires a considerable amount of shop work—sawing to length, cutting the seats for the tie-plates, making the bolt-holes, etc.—all of which is expensive. While the plan might be successful for light railways with small traffic, it is not likely to be practicable for main lines or heavy traffic. As to the supply of material, it will be noted that one rail 30 feet long will only make two ties.

These ties have been tried on two or three railways in Germany, and a few have been tried in Belgium. They are said to have given satisfactory results as to maintenance, but it is not probable that they will be adopted to any extent.

Metal ties at switches and frogs.—On the Prussian state railways the metal ties are employed at switches and frogs. The ties are of the modified "Berg-and-Mark" type, 11.2 inches wide over the bottom and 3 inches deep. Bolted clamp fastenings are used. For a length of 81.45

feet over a switch and frog, there are 40 ties of various lengths, from the ordinary length of 7.87 feet to 14.76 feet beyond the frog; this long tie holding all the rails. The tie to which the switch-lever and apparatus is fastened is 12.46 feet long. The ties are variously spaced; 30 inches center to center at the frog, 32.4 inches at the switch, and up to 37.2 inches intermediate. At the switch there is a bed-plate 18.6 feet long by 14.8 inches wide under each line of rails, covering 8 ties. The frog and guard rails cover 5 ties. At crossings and slip switches the arrangement of the ties is rather more complicated.

The work of laying and fitting switches and frogs on these ties is probably more difficult than with wooden ties, but when once laid they require much less attention, owing to the secure fastenings and the accurate maintenance of the gauge, and the track is certainly much safer than with the ordinary arrangement of frogs and switches. The fact of the introduction of metal ties at these points is an evidence of the favor with which such ties are considered.

SUMMARY OF METAL TRACK FOR GERMANY.

Railways.	Year.	Ties.	Longitudinals.	Total track.
Prussian state railways:		*Miles.*	*Miles.*	*Miles.*
Berlin division	1884	1.24	473.06	474.30
Elberfeld division	1887	762.60	93.00	855.60
Cologne division (R)	1888	450.69	162.06	612.75
Cologne division (L)	1888	943.96	241.45	1,185.41
Frankfurt division	1884	37.82	634.88	672.70
Erfurt division	1889	251.10	....	251.10
Hanover division	1884	107.26	340.38	447.64
Magdeburg division	1884	126.48	13.02	139.50
Bromberg division	1888	....	191.93	191.93
Bavarian state railways	1889	140.00	399.00	539.00
Baden state railways	1889	567.27	2.61	569.88
Wurtemberg state railways	1889	350.00	16.74	366.74
Alsace-Lorraine railways	1889	312.02	583.69	895.71
Main-Neckar Railway	1889	58.13	....	58.13
Hesse Louis Railway	1888	300.08	79.36	379.44
Lower-Palatine Railway	......	80.00	....	80.00
Hollenthal Railway	......	4.75	....	4.75
Total included in this report	......	4,493.40	3,231.18	7,724.58
Official total at end of 1888	......	5,224.12	3,562.52	8,786.64

AUSTRIA AND HUNGARY.

General Remarks.—Metal tracks of different kinds have been tried on the most important railways, and the two types which have been most widely experimented with are the Heindl type of cross-ties and the Hohenegger type of longitudinals. On the lines where wooden ties are used metal tie-plates are frequently employed to prevent the cutting of the wood by the flange of the rail; they are not generally used on every tie, except on very sharp curves; they are generally heavy plates about 5.25 by 7.50 inches and .40-inch thick under the rail, with a rib on one or both sides. The spikes pass through the plate, and hold both rail and plate. The following notes as to the track are taken from an article of mine, "The Austria-Hungarian railways," published in the Railroad Gazette, New York, August 19, 1887:

> The iron rails are from 39.6 pounds per yard in lengths of 18.14 feet to 75 pounds per yard in lengths of 19.68 feet. The steel rails are 64.5 pounds per yard in lengths of 22.79 feet, 66.3 pounds per yard in lengths of 29.52 feet, and 76.5 pounds per yard in lengths of 22.79 feet; the second of these steel rails is the standard. Formerly insistent joints were used, the wooden joint-ties being 8.2 feet long, 10 inches wide on top, 11⅘ inches wide at the bottom, and 6 inches thick. Suspended joints are, however, now being used. The ordinary ties are about 8.2 feet long, 6 inches wide on top and 11⅘ inches wide at the bottom; in some cases both sides have a slope, in others one side is vertical and the other slanting, while others have the sides vertical, but with the corners beveled off to the top width. Gauge-rods are sometimes used on curves.

These countries are said to be among the most favored countries in Europe as regards the production of timber.

The following table, showing the growth of the railways and the steady increase in the use of metal track, is from the report of Mr. Bricka to the minister of public works, France, in 1885.

Mileage of railways of Austria and Hungary.

Year.	Main lines.	Local lines.	Total track.	Wooden ties.	Metal longitudinals.	Metal cross-ties.
1878	10,600.14	625.58	14,977.96	14,966.18	11.78	....
1879	10,621.22	681.38	15,086.46	15,071.58	12.40	2.48
1880	10,668.34	718.58	15,237.74	15,219.14	16.12	2.48
1881	10,626.80	843.34	15,351.20	15,324.54	18,60	8.06
1882	10,970.28	859.94	15,860.22	15,821.78	27.28	11.16
1883	11,078.16	1,271.62	16,523.00	16,464.72	42.16	16.12
1884	11,647.32	1,607.04	17,681.78	17,606.76	47.74	27.28

AUSTRIAN STATE RAILWAYS.—Some years ago a few metal ties of the "Atzinger" type, designed by Mr. Atzinger, an engineer, were laid on a length of about 2.48 miles on the Francis Joseph Railway, which is now a part of the state railways system. They were similar to the "Berg-and-Mark" type of tie, with the Ruppel plan of fastenings (see Germany). In 1879 wrought-iron ties, weighing 154 pounds each, were laid for a length of about .85 mile between Nussdorf and Kahlenbergerdorf. In 1882 mild steel ties of the same type were laid for a length of 1.75 miles between the latter town and Klosterneuborg; these were 7.87 feet long, 4.8 inches wide on top, 9.6 inches wide at the bottom, 3.2 inches deep, weighing 118.8 pounds. The ends were closed. On this single-track line there was an ordinary traffic of forty trains per day, with seventy trains on fête days.

The Serres-and-Battig system of longitudinals (Plate No. 11) was also tried about ten or twelve years ago. They were laid in 1877–1879 for a distance of .62 mile on the line from Vienna to Bruck, .62 mile on the line from Oravitza to Anina, and also in the station at Budapesth. The longitudinal consists of two beams, forming a Λ or a ⅄ with a very short stem when assembled together. At the lower edge of each beam is a horizontal flange, and the upper part is vertical for a short depth; between these vertical parts rests the web of a flangeless T rail, secured by bolts passing through the web and the tops of the two beams. The objects of this system are as follows: (1) To make a track which the weight of trains will tend to keep together or consolidate; (2) to make the wearing part of the rail renewable; (3) to avoid the use of small pieces of material. The longitudinals are connected at their joints by flat plates bolted to the horizontal bottom flanges. The transverse connections consist of deep bars of ├┼┼┤ section passing through the longitudinals, notched to receive the web of the rails, and resting on the top of the horizontal flanges of the longitudinals. The head of the rail is 1.32 inches deep; the vertical part of the longitudinals upon which rests the head and between which lies the web of the rail, .60 inch thick, is 2.48 inches deep, and from thence to the level of the top of the horizontal flanges is 2.98 inches; these flanges are 2.48 inches wide. The width of the longitudinals at the bottom is 7.64 inches inside and 12.60 inches over the flanges. The thickness of the vertical and horizontal parts is about .60 inch and of the inclined parts about .24 inch to .38 inch. The tie-bars extend beyond the longitudinals and are placed about 7.87 feet apart; they are 4.48 inches deep, about .32 inch thick, with flanges about 1.8 inches wide, the two middle ones being rather narrower. The bolts holding the rails and longitudinals together are .76 inch diameter, with oval bolt holes to allow for expansion. The weight of the track was about 258 pounds per yard. The line was standard gauge, single track, with the ballast deep under the longitudinals and on the outside level with the bottom of the rail head. For curves, the parts are bent at the works. When tried in Belgium this track was unsatisfactory, owing to the poor quality of the iron and faulty construction, but in Austria it has given good results. A piece of track .62 mile long laid in 1879, near Temesvar and Oravitza, included curves of 374 feet radius and a grade of 2 per cent.; there was a heavy traffic, with trains hauled by engines having three and four coupled axles. This section of track was found by Mr. Bricka in 1885 to be in good condition; the repairs had been few, and the maintenance was reported as having been more economical than with wooden ties. Further experiments, on a more extended scale, were to be made. Some of this track was still in service in 1887. It is said to have given especially good results at stations, where the maintenance is difficult, and where it is necessary to avoid a frequent renewal of the ties. The comparison of cost has been given as follows:

Materials.	Ordinary track with wooden ties.	Serres and Battig system of metal track.
Rails	$3.36	$1.98
Ties or longitudinals	1.34	4.02
Fastenings	.72	.06
Ballast	1.30	.86
Laying	.36	.14
Total cost per yard	7.08	7.06

The most extensive experiments, however, have been with the "Heindl" type of cross-tie (Plate No. 14), the invention of Mr. Franz Heindl, general inspector of the state railways. These ties have been laid as follows:

Where laid.	Year.	No. of miles.
On three divisions	1883	1.302
In the Arlberg tunnel (first track)	1884	6.634
In the Arlberg tunnel (second track)	1885	6.634
On secondary railways	1886	13.020
Total	......	27.590
At stations (side-tracks, etc.)	......	24.800
Total to 1888	......	52.390

The ties are of steel, of inverted trough section, having the lower part of the sides vertical. They are 7.87 feet long, 6 inches wide on top, 10.4 inches wide at the bottom, 4 inches deep with the sides vertical for 2.4 inches from the bottom; .32 inch thick at the sides and .40 inch on top. The weight is 158.4 pounds per tie. The fastenings are rather complicated and are composed of a number of pieces. Each rail rests on a tie-plate which gives the inclination of 1 in 16; an angle clamp (⌐) is placed on each side, the top resting on the tie with its end fitting into a notch in the tie-plate and the lug fitting into the elongated bolt hole in the tie; the adjustment of gauge is effected by using different sizes of these clamps. Lying in a groove in the top of this clamp is another clamp with one end projecting over and bearing upon the flange of the rail. A ⊥-headed bolt, with the nut on top, holds these parts together. The tie is horizontal throughout its length. Formerly the top table was bent down at the end to a depth of 5.2 inches, and the sides bent round; now, however, the projecting end of the top table is cut to such a shape that when bent down it effectually closes the ends of the tie. For a rail length of 24.6 feet the ties are spaced 20 inches apart at the joints, 32 inches next to the joints, and 36 inches center to center of intermediate ties. The rails are of flange section, about 4.9 inches high, with a head 2.32 inches wide and a flange 4.48 inches wide. The joints are spliced by angle-bars with four bolts. The ballast is of earthy gravel. The weight of track complete is 2,833.58 pounds for a rail length of 24.6 feet, or 345.6 pounds per yard.

The ties for the secondary railways are of similar type to those already described; 5.2 inches wide on top, 9.2 inches wide on the bottom, 3.2 inches deep; thickness of sides .32 inch, and of the top .34 inch. The weight is about 123.2 pounds.

In Arlberg tunnel coke-burning engines are used. For particulars of this track, see a note on "The Heindl ties" further on.

NORTHERN RAILWAY.—In 1883 ties of the "Heindl" type were laid for a length of 1.24 miles between Vienna and Cracow, on the Emperor Ferdinand Northern Railway. Part was laid in gravel and part in broken stone ballast. Mr. Bricka states that he noted that the noise of the passage of trains was no more disagreeable on this track than on the parallel track laid with wooden ties. He notes this as an interesting point, as showing that with ties of proper section and sufficient weight the vibrations are not caused, or that with a good form of metal track as a whole they are considerably diminished. These ties are of similar dimensions and weight with those on the state railways.

AUSSIG AND TEPLITZ RAILWAY.—Steel cross-ties of the Heindl system were laid in 1883 for a length of .62 mile. They are of similar weight and dimensions with those on the state railways.

GALICIAN (CARL-LOUIS) RAILWAY.—A length of .62 mile was laid with the Heindl system of steel cross-ties in 1884. These also are similar to the ties in use on the state railways.

NORTHWESTERN RAILWAY.—On this railway metal longitudinals have been tried since 1876, and the following very complete description of the track was furnished in March, 1888, by Mr. Hohenegger, chief engineer, for the purpose of this report. (See plate No. 14.)

The line between Vienna and Tetschen has 59.51 miles laid with metal track, which have been laid as follows:

Year.	Form.	No. of miles.
1876	I	2.54
1877	II	2.45
1878	II	4.70
1880	II	3.33
1881	II	2.58
1882	III	7.87
1883	III	15.31
1884	III	6.20
1885	III	6.32
1886	III	4.33
1887	III	3.87

Of this length the alignment is as follows:

	Miles.
On tangents	37.21
On curves of:	
9,840 to 3,280 feet radius	7.44
2,952 to 1,968 feet radius	3.35
1,640 to 1,148 feet radius	11.00
984 to 935 feet radius	.51

There are daily, in both directions, two fast express trains, two express trains, eight accommodation trains, and at least ten freight trains. The passenger engines weigh 42 tons each, in working order, and have a weight of 12.4 tons on the driving axle; the freight engines weigh 45 tons in working order and have a weight of 11.25 tons on the driving axle.

The track is laid with three forms of metal longitudinals: 2.54 miles of No. I 13.07 miles of No. II, and 43.90 miles of No. III. Those of forms No. I and No. II are made from old iron rails, and weigh 51.90 pounds and 60.95 pounds per yard, respectively; No. III are of mild steel, made by the Thomas process, and weigh 58.80 pounds per yard. There is no protection against rust, the longitudinals being laid in the state in which they leave the rolls; no rust has thus far been observed. The longitudinals are manufactured at the Teplitz Rolling Mill and Bessemer Works, *Price.*—The prices are as follows, for delivery at railway stations: No. I, $5.94 per 220 pounds, or about $60 per ton; No. II, $3.46 per 220 pounds, or about $35 per ton; No. III, $4.56 per 220 pounds, or about $46 per ton. For the manufacture of Nos. I and II, the railway company furnished the necessary old rails, which were accepted and accounted for at $1.92 per 220 pounds, or about $20 per ton.

Renewals.—Of form No. I, after eleven years' service, one longitudinal was renewed on account of the opening of a welded joint; this is 0.0001 per cent. of the whole. Those of form No. II were made from old flange rails, which were simply welded together, and rolled in three sizes; of the first delivery, after ten years' service, 7.08 per cent. had to be renewed on account of imperfect welding. Those of form No. III are, so far, without defect or failure, and not one piece has been renewed.

Curves.—The longitudinals of forms Nos. I and II are rolled straight, and the holes for the rail-bolts were spaced according to the radius of the various curves; those of form No. III are bent, while hot, to the required curve. Those of form No. I were all of equal length, because, in consequence of the considerable distance left between the ends at the joints, a shortening on the curves can easily be effected by laying them closer together. Nos. II and III are made of shorter length for the inner side of curves, a certain number being laid according to the shorter rail length and the radius of the curve.

Tie-rods.—These were originally used for Nos. I and II, because the longitudinals were only connected at the ends by transverse ties, the distance between them being 31.81 feet for No. I and 15.83 feet for No. II. An experience of several years has proved that tie-rods are not necessary for preserving the accuracy of the gauge, the transverse connections under the longitudinals being sufficient for this purpose; these connections placed at intervals of 9.84 feet answer the purpose.

Wear.—The only wear observed has been with some longitudinals of form No. I, in which the flange of the inner rail on curves has worn slightly into the top table.

Durability.—The life of the longitudinals of form No. I is estimated at about fifty years; those of No. II, made of old flange-rails, will hardly last as long, as, being made simply by welding the old rails together, a gradual opening of the welded joints must be expected, especially in those parts which correspond to the former web of the rail; the pieces which have required to be renewed have shown this defect distinctly. Those of form No. III, being of steel, will certainly last even longer than those of form No. I.

Fastenings.—The rail fastenings for form No. III (See plate No. 14) effectually prevent creeping of the rail on the longitudinal by firm hold of the clamp on the rail-flange and the rib of the longitudinal. The inclined outer face of the clamp admits of an adjustment of the gauge; this is effected by slacking one nut, which allows the clamp to rise and also move back; the rail is then shifted, the opposite clamp pushed down to a corresponding extent, and both nuts then screwed tight. The rail-flange butts against a boss on the lower side of the clamp, which thus receives all the force of the lateral thrust caused by passing trains, and transfers it to the rib of the longitudinal, thus protecting the bolt from wear.

Ballast.—The ballast is of river gravel, excavated gravel, and broken stone. The core of ballast inside the longitudinal is compressed, by tamping and by the pressure of passing trains, to such an extent that it can only be loosened by means of a pick; this compression extends nearly 12 inches below the lower edge of the longitudinal and prevents the quick drainage of water from between the rails, this prevention of the drainage varying with the degree of compression of the ballast. For this reason it is recommended that the ballast should be clean and of a character which will allow of the water passing through; where this can not be had, however, sufficient means for drainage must be provided. No heaving by frost has been observed on this track.

Rails.—The rails are of one flange section, weigh 58.75 pounds per yard. The joints are spliced by an inner straight plate, and an outer double-angle or channel plate;

four bolts are used. The outer plate was of symmetrical shape for Nos. I and II, and served to hold the head of the rail in horizontal position as well as to support it vertically. At each end the splice-plate bore against a rail-clamp bolted to the longitudinal, and thus prevented creeping; in this way the tendency to creep caused by the passage of trains was transmitted to the longitudinal, which was itself prevented from moving by its rigid cross connections. For form No. III the outer splice-plate is of unsymmetrical section, the upper flange being narrow; the edge of the lower flange bears against the rib of the longitudinal, thus increasing the resistance to the outward thrust of the rail. A bolt passing through this flange and the top of the longitudinal effectually prevents any creeping beyond that allowed by slight inaccuracies in drilling the bolt-holes. An inner angle-plate, bearing against the other rib of the longitudinal, completes the joint and makes a solid continuous track. With Nos. I and II the rail-joints are supported, but with No. III they are suspended.

The steadily increasing speed and weight of passenger trains made it necessary to employ heavier and more rigid locomotives, and this traffic nearly reached the limit of the power of resistance of the ordinary track with cross-ties. To strengthen this track by the use of oak ties, or even iron ties, in place of the usual pine ties, would have increased the expenses considerably without increasing in equal proportion the power of resistance of the track against lateral pressure on the many and sharp curves of the road. These reasons led to the adoption of track on metal longitudinals, after a preliminary trial had been made in 1876; but the great cost of such track made it necessary to study the matter more thoroughly. At the first, attention was directed to making use of old rails, which, in consequence of the increasing introduction of steel, would be obtained at very moderate prices. The success of the experiment permitted the adoption of iron track for other portions of the line in 1877, 1878, 1880, and 1881, but only to such an extent as old rails were taken up and welded together to form the longitudinals. These old iron rails becoming scarce, and the introduction of the Thomas-Gilchrist process for the manufacture of mild steel, which made the cost of this material very moderate, led naturally to the adoption of form No. III (See plate No. 14), made of mild steel. Another reason for adopting the longitudinal stringer system of track was the proportionately weak section of the flange-rails used, weighing only 64.38 pounds per yard. In view of the increasing weights of the locomotives, this gave the company and its engineer the alternative of increasing the weight of the rails to 100.43 pounds per yard, or of adopting a still lighter rail and obtaining the necessary strength by means of a strong longitudinal or stringer. Whether this method of obtaining a strong track is a correct one, the future will demonstrate.

The behavior of the track laid with form No. III has been very satisfactory. On the part laid with Nos. II and I, it was found necessary to remove the broad iron cross-ties which were laid under the joints of the longitudinals, according to the Hilf system (See Germany), and to replace them by plain angle-irons. Their purpose is merely to maintain the width of the gauge, and not to support the ends of the longitudinals like abutments. The track stands admirably and requires little or no labor for maintenance and surfacing, either on the straight portions, which are in lengths of 3.72 to 4.34 miles, nor on sharp curves. On the straight portions no such swinging and rolling motion of the cars can be observed as is the case on track laid with cross-ties. There is no trouble with the attachments, the nuts being held in position by nut-locks, and tightening up of the nuts is rarely necessary. The trackmen formerly required to redrive the spikes for track with wooden cross-ties can now be employed on other track work. In consequence of the continuous support of the rails, no rails or splice-plates on this metal track have been broken since the same has been in service. The economical value of the use of metal track has been worked out by calculation.

Wooden ties.—On the guaranteed system of this railway impregnated oak ties are used on all portions over which express trains are run; impregnated pine ties are used at stations, on side tracks, and on branch lines. The reason for this is that the terminus of the road is on the Donau River, so that the oak brought by water from Hungary can be bought at a comparatively low price. On the supplementary system of the railway, which requires in addition the cost of freight of oak ties to Vienna, a distance of 200 miles, oak ties had to be abandoned on account of the increased cost, and pine ties are therefore used. These conditions, as already stated, were the cause of the introduction of metal track, and at present, of the total length of 83.70 miles over which express trains are run, 64.3 per cent. is laid with this track. The remaining parts will be renewed with metal in accordance with the amount appropriated for this purpose. These parts are now laid with impregnated pine or spruce ties, but it must be remarked that metal tie-plates .4 inch thick are laid on each new tie that is put in; on curves of 1,640 feet radius, and less, these plates have a rib fitting into a groove across the tie, and the rail is fastened by bolted clamps. Oak ties cost at present (1888) about 84.96 cents each, not impregnated; this is in consequence of the high German duty on timber which prohibits its export, but only a few years ago the price was $1.08 per tie. Pine ties, not impregnated, cost from 38 to 43 cents each. Oak ties were impregnated with oil of creosote, on the Bethel process, at a cost of 22 cents per tie; chloride of zinc, of 1.5 degrees Beaumé density, by the Burnett process, is now used and costs 17 cents per tie. Pine ties are impregnated with tar oil or creosote on the Blythe system, and partly with a solution of chloride of zinc of 1.5 degrees density, Beaumé, by the Burnett process, at a cost of 17.28 cents per tie. The life of an impregnated oak tie is estimated at twenty years, and the life of an impregnated pine tie at twelve years.

The following descriptions of the three classes of track are from drawings furnished by Mr. Hohenegger:

No. I.—The longitudinal was of the "Rhenish" type (See plate No. 12). It was 8 inches wide on top, 11 inches over the bottom, 2.88 inches deep; thickness of sides .3 inch, and of top table .32 inch. The rails were held by clamps bearing on the rail flange and the top of the longitudinal, and fastened by hook or L headed bolts. For tangents and curves down to 1,230 feet radius, the rails and longitudinals were 31.98 to 31.81 feet long, the joints of the former being about 40 inches from those of the latter. The ends of the longitudinals rested on saddle plates riveted to the ends of a cross-tie 7.87 feet long, 8 inches wide on top, and 12.8 inches wide on the bottom. There were two tie-rods to each rail length. For curves of 1,226.72 to 492 feet radius, the rails and longitudinals were 21.32 to 21.15 feet long, with a cross-tie at the joints of the longitudinals and two tie-rods to each rail length. The cross-ties were inclined at the ends to give the rails the usual inclination, and the longitudinals were fastened to them by ┌ clamps holding the rib. The tie-rods were .88 inch diameter, with a bearing plate and nut on the outer side of the rail. The rail fastenings were placed at intervals of about 32 inches with the longer rails, and about 31.6 inches with the shorter rails; at the joints they were closer together.

No. II.—The longitudinal was of a section somewhat similar to the Hilf or the original "Berg-and-Mark" types (See plate No. 12), but with a semi-cylindrical rib along the middle of the under side of the top table. For rails 31.98 feet long, the longitudinals were 15.90 feet long, breaking joint with the rails by about 11 inches. The ends of the longitudinals rested on saddle pieces fastened to cross-ties 7.87 feet long, 8 inches wide on top, 10.8 inches wide on the bottom; the cross-tie was horizontal, but the outer side of each longitudinal rested on a packing piece to give it the required inclination. The ballast was brought up level with the top of the longitudinals.

No. III. (See plate No. 14.)—The longitudinal is of a section similar to that of the "Berg-and-Mark" cross-tie, but has a rib along each side of the top table. It is 6.72 inches wide on top, 12 inches wide on the bottom, 3 inches deep, with the sides vertical for 1.84 inches from the bottom; the sides are .32 inch thick and the top table is

.36 inch thick. The fastenings, as already described, consist of bolted clamps bearing on the flange of the rail and the inclined face of the rib of the longitudinal, while at rail joints the bolts pass through the lower flange of the outer splice bar, which is of channel section. The longitudinals are 29.43 feet long, and the rails 29.52 feet long. The joints of the rails and longitudinals coincide. The ends of the latter rest upon a saddle made of a plate .40 inch thick, bent to shape to fit the interior of the longitudinal, and bolted to the end of an angle-iron cross-tie, 6.56 feet long, 3.2 inches wide, 4 inches deep, and .4 inch thick. The saddle is 16 inches long and 17 inches wide; the top is inclined 1 in 16 to give an inward inclination to the rail. The bolts pass through the saddle, longitudinal and clamp. There are two intermediate cross ties, spaced 9.77 feet from each joint tie, center to center; they are of angle-irons of the same size as those at the joints, but the saddle for the longitudinal is only 4.8 inches long. There are three bolts on each side of every rail joint; the next fastening is 22.2 inches away, center to center and the others are 30.4 inches apart center to center. All the nuts are fitted with nut locks; the nut lock consists of a square flat plate, with a slit in one side; the plate is prevented from turning and when the nut is screwed down upon it the slit piece is bent up against the side of the nut, thus preventing the nut from turning. The weight of this track is 2,791.58 pounds per rail length, or 283.72 pounds per yard.

Mr. Bricka, in his report to the minister of public works, France, in 1885, speaks very favorably of this latter form of track. The cost is about $5.31 per yard for No. III, $5.22 per yard for No. II, $6.60 per yard for No. I, and $5.12 per yard for track on impregnated oak ties.

HUNGARIAN STATE RAILWAYS.—The following particulars were presented by Mr. Kowalski at the International Railway Congress at Milan, Italy, in 1887:

In 1887 there were 3,000 metal ties in service, which had been laid in 1882 and succeeding years They were of the "Berg-and-Mark" type, with gib and cotter fastenings. Up to 1886 they were made of wrought-iron, but after that of Bessemer steel. The ties weighed 108.90 pounds each, and the fastenings 5.19 pounds per set; making a total weight of 114.09 pounds per tie. Up to 1886 they were employed only on the Mountain division between Piski and Petroseny, and they were all laid on curves of a radius of less than 984 feet. The speed of the trains was from 13.64 to 21.70 miles per hour. The track was laid with iron rails weighing 71.5 pounds per yard, and steel rails weighing 67 pounds per yard. The ballast was of broken stone. The metal ties cost $2.82 each, and the wooden ties 67½ cents each. The advantages of the former were in the simplicity of the attachments and the stability of the track. In 1887 the company began the work of gradually replacing wooden ties with metal ties on curves of 984 feet and under. The price of oak ties was still too low to permit of the introduction of metal ties on a large scale for tangents and flat curves, but nevertheless, it was proposed to substitute metal for wooden ties at switches and the approaches to important stations, as the former were considered advantageous for such a locality.

HEITZING AND PERTCHTOLDSDORF STEAM TRAMWAY.—This is a standard-gauge country tramway, built partly along the public highway and partly across country. It is 6.43 miles long; 3.9 miles, or 60 per cent. of its length, are on roads and streets, and the remaining 40 per cent. is practically a light railway. Along the roads the track is laid on one side, next to the gutter. The track is on the Hartwich system, with flange rails carried on longitudinal steel stringers, connected at intervals by tie-bars. The longitudinals are of a section similar to that of the original "Berg-and-Mark" cross-ties; they are 4.6 inches wide on top, 8.4 inches wide at the bottom, 2.4 inches deep, with the sides vertical for about .8 inch from the bottom. The weight is about 28.72 pounds per yard. At the joints the ends of the longitudinals rest on a saddle piece of such section as to fit the interior of the tie. The rails are of flange section, 4 inches high, flange 2.72 inches wide, head 1.52 inches wide, with the top table at an angle, higher on the outer than on the inner side; the weight is about 31 pounds per yard. The fastenings consist of a riveted lug for the outer flange, and a hook-headed bolt, with clamp washers, for the inner flange; the heads of the bolts are inside the longitudinal. The rail joints are spliced by straight splice plates. The tie-bar is 5.74 feet long, 2.4 inches deep, .32 inch thick; it is notched for the bottom of the sides of the longitudinal, and at each end is keyed a ∩ piece against which the outer side of the longitudinal bears. In the streets there is a guard rail attached to the longitudinal, leaving a groove 1.20 inches wide for the wheel flanges. In streets the longitudinals are laid on stone blocks and ballast is filled in nearly up to the under side of the rail-heads. In country roads a trench is dug for each line of rail, broken stone laid for the longitudinals to rest on, and ballast then filled in to the underside of the rail heads, the heads just projecting above the street level. The engines are ordinary steam motors, boxed in. The older ones had four wheels, all coupled, and weighed 29,700 pounds. The later engines have six wheels and weigh 39,600 pounds.

TIES.

The Heindl ties.—The system of track with steel cross-ties, invented by Mr. Heindl (See plate No. 14), has already been described as used on the Austrian state railways. In 1888 Mr. Heindl sent a communication in relation to this track, which had been laid as follows, up to the end of 1887:

Year.	No.	Railway.	Location.	Maximum grade.	Minimum curve.	Length.	Total.
				Per ct.	*Feet.*	*Miles.*	*Miles.*
1883..	1	Austrian state	Breitenschutzung-Schwanenstadt.	.37	1,869.60	.62	......
1883..	2	...... do	Kosten-Dux	1.03	931.52	.62	......
1883..	3	...... do	Grybow-Ptaszkowa	1.80	984.00	.06	......
1883..	4	Bavarian state	Landshut-Neuenmarkt.	1.25	1,148.00	.17	......
1883..	5	Emperor Ferdinand's Northern.	Raigern-Durnkrut	.04	4,352.56	1.24	......
1883..	6	Aussig-Teplitz	Ullersdorf-Dux	.86	1,554.72	.62	......
							3.33
1884..	7	Galician, Carl-Ludwig	Ulai-Bochnia	.06	3,109.44	.62	......
1884..	8	Austrian state	Arlberg Tunnel, track No. 1.	1.50	981.00	6.63	......
1884..	9	Alps Mountain Company	Leoben-Leegraben	4.12	492.00	.37	......
							7.62
1885..	10	Austrian state	Arlberg Tunnel, track No. 2.	1.50	984.00	6.63	......
1885..	11	Bavarian state	Stockheim-Ludwigstadt	2.50	984.00	19.10	......
							25.73
1886..	12	Austrian state	Liveric-Knin	2.00	934.80	13.02	......
1887..	13	Bavarian state	(Renewals)	......	......	35.34	......
1887..	14	......do	(Laying second track)	......	......	31.00	......
							79.36
		Total					116.04
Side-tracks at stations on the Austrian state railways							24.80
Grand total at end of 1887							140.84

The following is the principal part of Mr. Heindl's communication:

The heaviest traffic has been on line No. 5, over which 20,000,000 gross tons had been hauled and express trains had run at a speed of 50 miles per hour. The traffic on line No. 6 has been about the same. The locomotives have a weight of 6 to 7 tons per wheel, except on lines No. 9 and No. 12; the former is a mountain line, and the latter is a part of the secondary railways. The cost of maintenance is greater than that of wooden ties only during the first year, and afterward it becomes considerably less. In 1886 the cost of maintenance of the metal track on line No. 5 was $164.63 per mile, while that of adjacent track on wooden ties was $266.25 per mile. The durability of the iron track depends principally upon the construction, because with a defective method of attaching the rails, a mechanical destruction and wear of the track at the fastenings is inevitable. Experience has shown that a light track with such defective fastenings will scarcely last more than a few years under heavy traffic. With a carefully constructed track, however, the durability of the ties and attachments will be greater than that of the rails, which are directly exposed to the shocks and wear from the wheels. The principal conditions for a superstructure with metal ties are as follows: First, sufficient weight of ties and rails to insure stability; and, second, the use of an efficient fastening for the rails. The ballasting for a track on iron ties does not require more attention than that for track with wooden ties. The same kind of ballast can be used, but care must be taken to keep it free from earthy or clayey matter. The material fills the interior of the tie and in time forms a compact body which adds considerably to the stability of the track. With a metal track there is a greater security in the track and greater safety in operation. The durability and the avoidance of repairs or other work except tamping must certainly lead to economical results even if the first cost be greater. A well-constructed track on metal ties is so superior to one on wooden ties, as regards safety for the traffic, that an increased first cost might well be incurred, especially for main lines with heavy traffic.

Whatever may be the advantages of this system, it is certainly lacking in simplicity, which is a very serious defect, as it must inevitably lead to difficulty in laying and maintaining track, unless well trained, skilled, and expensive labor is employed. As already noted, this important feature of simplicity is one which as a rule is apparently given little attention in Europe.

SUMMARY OF METAL TRACK FOR AUSTRIA AND HUNGARY.

Railways.	Longitudinals.	Cross-ties.	Total.
	Miles.	*Miles.*	*Miles.*
Austrian state	.62	52.39	53.01
Northern		1.24	1.24
Aussig and Teplitz		.62	.62
Galician (Carl-Ludwig)		.62	.62
Northwestern	59.51		59.51
Hungarian state		1.50	1.50
Heitzing and Pertchtoldsdorf	6.43		6.43
Total	66.56	56.37	122.93

SWITZERLAND.

GENERAL REMARKS.—Metal track is in quite extensive use in this country and has been given a thorough trial with eminently satisfactory results, some of the railways having now definitely adopted metal ties. At present they are used mainly on lines having the heaviest traffic, as on these lines the ties give greater security than wooden ties, if they are of sufficient weight, have well proportioned dimensions, and if the right means of attachment are employed. Another reason for using metal ties is that it is getting more difficult year by year to obtain oak ties in sufficient quantity.

Mr. Bricka, in his report to the minister of public works (France) in 1885, gives the following statement of the mileage of the track of Swiss railways for 1883 and 1884:

Year.	Main lines.	Total track.	Wooden ties.	Metal ties.
	Miles.	*Miles.*	*Miles.*	*Miles.*
1883	1,165.60	1,695.08	1,633.08	62.00
1884	1,165.60	1,696.94	1,582.86	114.08

The chief engineer of the Jura, Berne and Lucerne Railway sent me in August, 1889, the following statement of the mileage of the railway track in Switzerland to date:

	Inclusive of the Brunig line.	Exclusive of the Brunig line.
	Miles.	*Miles.*
Total length	1,697.65	1,668.83
Length in operation	1,777.54	1,749.61
Length of track with:		
Wooden ties	1,973.46	1,967.24
Metal ties	397.40	372.31
Total length of track	2,370.86	2,339.55

GOTTHARD RAILWAY.—During the first construction of this celebrated railway, from 1879 to 1882, timber ties were used. In the summer of 1883 experiments were made with different types of metal track. These experiments led to the adoption of metal ties, and in 1884 it was decided to use such ties only in future; after further experiments a form of tie was definitely adopted in 1887. (See plate No. 15). In the original construction, the track was laid with steel flange rails, weighing 73.65 pounds per yard, on wooden ties. The rails were 5.2 inches high, with a flange 4.4 inches wide and a head 2.4 inches wide; the top table was flat, with top corner curves of .56 inch radius. The ties were 8.2 feet long, 9.6 inches wide on the bottom, 6.4 inches wide on top, 6 inches thick, the upper edges being beveled to a depth of 1.6 inches.

The rail joints were suspended, and metal tie-plates were placed under the rails at the joint ties as well as on some of the intermediate ties on curves. These plates were 6 inches long, 7.6 inches wide, and .44-inch thick, with a rib on the outer side. There were three spikes to each plate; they were of octagonal section, with hooked heads, and were driven into holes bored through the ties. The inclination of 1 in 16 was given to the rails by adzing out a seat on the tie. The joints were spliced by angle-bars and four bolts.

Several systems of metal track have been tried, among them the following:

(1) "Vautherin" tie, of modified section, with heavy ribs instead of flanges on the bottom edges; 4.4 inches wide on top, 7.84 inches wide at the bottom inside and 9.2 inches wide over the ribs, 3 inches deep, top table .40 inch thick; weight about 123.2 pounds. There were ten ties to a rail length. These were laid for a length of 577.28 feet in the tunnel and about 1,968 feet on the line between Bellinzona and Giubiasco.

(2) Hilf tie; similar to the "Berg-and-Mark" type, the lower part of the sides being vertical; 4.8 inches wide on top, 8.8 inches wide on the bottom, 2.4 inches deep; top table .4 inch thick; weight about 110 pounds. These were laid for a length of 2,296 feet.

(3) Hilf tie; of similar section to the above, but made of mild steel; 5.2 inches wide on top, 9.2 inches wide on the bottom, 2.4 inches deep, with sides vertical for 1 inch from the bottom; top table .4 inch thick and sides .36 inch; weight about 110 pounds. These were laid for a length of 984 feet.

(4) Lazar tie; this was of **T** section, with the sides bent down slightly; 10 inches wide on top, 8.8 inches being horizontal; middle rib 3.2 inches deep, edges turned down .8 inch; weight 134.2 pounds. These were laid for a length of 984 feet.

(5) Hohenegger system of longitudinals (See "Austria"). This track was laid for a length of 1,640 feet in the tunnel and on the line between Bellinzona and Giubiasco.

After these experiments a cross-tie of rounded trough section was adopted, with the top table thickened by adding metal on the upper side; 4.8 inches wide on top, 8.16 inches wide inside at the bottom, 9.336 inches wide over the ribs, 3.2 inches deep; corners, 1.6 inches radius; sides 28 inch thick, and top 36 inch thick; weight, 119.9 pounds. In December, 1889, Mr. Bechtle, the chief engineer, reported that there were 37.25 miles laid with metal track.

The preliminary trials, made about 1885, showed that with bad ballast the maintenance of track with metal ties cost more than that of track on new wooden ties, but that with good ballast the cost was less. The ballast now used is broken stone.

The type of tie definitely adopted in 1887 (See plate No. 15) is slightly modified from that last described, but is of varying width and depth, somewhat resembling the "Post" tie. At the rail seat it is 4.6 inches wide on top, 8.196 inches wide at the bottom inside, and 9.38 inches wide over the ribs; 3.4 inches deep; thickness of top table .40 inch, and of sides .28 inch; corner radius, 1.6 inches. Inside the rail seat it is of similar width, but only 3.24 inches deep, and the top .32 inch thick. At the middle it is of ∩ shape, 2.56 inches wide inside near the top, 3.46 inches wide inside at the bottom, 5.44 inches deep. The top table of the tie is horizontal at the middle, with a flat curve to the rail seat, which is inclined 1 in 20, and another flat curve from the outer side of the rail seat. At the ends the top table is bent down to a radius of .36 inch, and the depth is 4.8 inches. The total length of the plate from the bottom of one end to that of the other is 8.53 feet. The weight of the tie is 127.6 pounds. The bolt holes are 1.92 inches by .84 inch, with rounded corners, and 3.72 inches apart in the clear. The rail fastenings are on the Ruppel plan (See "Germany—Prussian state railways"); the inner side of the clamp bears on the flange of the rail, the outer side rests on the tie and has a lug fitting into the bolt-hole in the tie; tee-headed bolts are used, with the nuts screwing down on the rail clamps. For a rail length of 26.24 feet there are ten ties; the joint ties are spaced about 11.30 inches apart center to center, the ties next to the joints 30.5 inches, and the intermediate ties 34 inches apart. For a rail length of 39.36 feet there are fifteen ties; the joint ties are spaced about 11.30 inches apart, the ties next to the joints 29.15 inches, and the intermediate ties about 33.25 inches. The cost of maintenance, exclusive of renewals, is said to slightly exceed that of track on wooden ties.

Switches and crossings are laid on the steel ties. At the heel of the switch a tie of extra size is used, being 8 inches wide on top and 11.2 inches wide on the bottom, while the others are 4.8 inches wide on top and 9.336 inches on the bottom. With a stock rail 22.96 feet long, and a switch rail 16.40 feet long, there are eight ties, including one at the point and one at the heel, spaced 28.52 inches apart center to center. On these ties are bolted two plates 17.38 feet long and 18.4 inches wide, one on each side of the track, and on these are placed the rails. Hand-lever switch apparatus is bolted to a plate resting on the ends of two ties of extra length.

Mr. Bricka states in his report that in 1885 metal ties were laid for a length of 15.5 miles, and he gives the following statement of the mileage of the track in 1884:

	Miles.
Main lines	148.80
Total track	204.60
Wooden ties	202.12
Metal ties	6.82

NORTHEASTERN RAILWAY.—Metal ties were first used in 1880; the "Vautherin" and "Berg-and-Mark" types were tried, and the latter was adopted. They are 7.87 feet long, 5.2 inches wide on top, 9.2 inches wide at the bottom, and 3 inches deep, with the lower part of the sides vertical for 1.6 inches from the bottom; the top table was .32 inch thick, with a rib on the under side 1.6 inches wide, making the thickness .44 inch. The weight was 117.7 pounds. The ends were closed. At the middle the tie was horizontal, but at 22 inches from the middle they were bent up 1 in 16 for a length of 14 inches to form the rail-seat; thence the ends were horizontal, but higher than the middle portion. The rail fastenings are of the Roth-and-Schuler type, as used on the Baden state railways (Germany); a gauge washer on the bolt takes the thrust of the rail, and the clamp bears on the tie and the rail flange. In 1884 there were 42,358 ordinary ties and 2,512 special ties at switches; in 1885, 42,000 ties were laid. A modified form was adopted in 1885; it is of the same type, length and weight, but the top table is .36 inch thick instead of .32 inch; the sides are rather thinner, and there is a rib on each bottom edge. The rail joints are spliced by angle-bars 21.20 inches long, with four bolts. At the joints the ties are spaced 24 inches apart center to center, 32 inches apart next to the joints, 34 inches spacing for intermediate ties. These ties have given good results in regard to maintenance.

The ties used at frogs and switches are of the Hilf section, similar to the "Berg-and-Mark" type, but with a longitudinal middle rib, making them of m section. They are 7.2 inches wide on top, 12 inches wide on the bottom and 2.4 inches deep, the sides being vertical for 1.2 inches from the bottom. The thickness averages .32 inch, and the weight is 58.5 pounds per yard. Between the switch and frog, ordinary Berg-and-Mark section ties are used, with bolt holes in the top table, and weighing about 45 pounds per yard. At switches the ties are spaced about 30.28 inches center to center. Under each line of rail is a plate about 18.76 feet long and 12.8 inches wide, to which the rails are bolted and which is itself bolted to the ties; upon this the switch rails move. The two ties at the point of the switch are about 13.12 feet long, extending outside the track on one side to hold the switch stand and lever. At a No. 9 frog there are four ties; the inner ones, at the frog point, are spaced 28.56 inches center to center, and the outer ones 26.60 inches. On these four ties is a plate 6.56 feet long, and 16.8 inches wide, to which the rails are bolted, and which is bolted to each tie by two bolts.

Mr. Bricka, in his report, 1885, gives the following statement of the mileage of this road for 1884; and 21.08 miles more were laid in 1885:

	Miles.
Main lines	403.62
Total track	596.44
Wooden ties	573.50
Metal ties	22.94

WESTERN AND SIMPLON RAILWAY.—Steel ties of the "Berg-and-Mark" type and similar to those in use on the Elberfeld division of the Prussian State railways, were tried about 1881. They weighed about 100 pounds each. The engineers thought the maintenance expenses were greater at first, owing to the difficulty of ballasting, but the track was very elastic and the riding easy. In 1884 there were about 34.10 miles laid. Mr. Bricka stated that the introduction of metal ties had reduced the prices of wooden ties as follows: Oak, reduced from $1.20 or $1.30 to 90 cents per tie; larch, reduced from 80 or 90 cents to 60 or 70 cents per tie. For rails 19.68 feet long the ties were spaced 20.08 inches apart, center to center, at the joints, and 36.38 inches intermediate. Mr. Bricka gave the following statement of the mileage of track up to 1884:

	Miles.
Main lines	368.90
Total track	492.28
Wooden ties	473.68
Metal ties	18.60

The type of tie adopted in 1887 (See plate No. 15) is of inverted trough section, broad and shallow at the ends and narrow and deep at the middle, being of fish-bellied shape in elevation. The cross-section is similar to that of the "Berg-and Mark" type. The tie is bent to a curve with a radius of 49.26 feet to give the rails an inward inclination. It is 7.54 feet long over all, 9.2 inches wide over all at the ends, narrowing to 4.8 inches at the middle, and flaring out to 11.2 inches at the extremities; it is 4.4 inches deep at the middle, 2.4 inches deep for the greater part of its depth, and the ends are curved down and project below the body of the tie, being 4 inches deep. At the rail seat it is 5.2 inches wide on top, 9.2 inches wide at the bottom, 2.4 inches deep, with the sides vertical for 1.04 inches from the bottom. At the middle it is of ∩ section, with nearly vertical sides and round top corners; it is 4.8 inches wide at the bottom and 4.4 inches deep, with the top flat for a width of about 2.4 inches. The thickness is .28 inch at the sides, .36 inch on top, and .52 inch along the middle of the top table, the extra thickness being given by a rib 1.44 inches wide on the underside of the top. For rails 19.68 feet long, the joint ties are spaced 20.08 inches apart, center to center, and the intermediate ties 36.68 inches apart. The rails are of flange section, secured by gib and cotter fastenings. The outer flange is held by a gib; the inner flange is also held by a gib, and a third gib is placed back to back with the second one and the vertical cotter driven between them, the object of the third gib being to increase the bearing of the cotter. At each rail seat there are two holes in the tie; the outer one is 1.56 inches long at right angles to the rail and .72 inch wide; the inner hole is 2.624 inches long and .72 inch wide; they are 3.36 inches apart in the clear. The gibs are .68 inch thick. The cotter is 5.96 inches long, .68 inch thick, 1.07 inches wide at the top, and .76 inch wide just above the point. Inner and outer gibs of three different widths are used for the adjustment of the gauge; they allow a widening of .16 to .64 inch, and raised numbers on the side enable them to be easily distinguished. The gauge on tangents, and on curves of over 2,955.8 feet radius, is 4.71 feet; at the ends of curves of 1,315.28 feet to

2,952 feet, the inner rail is set out to give a gauge of 4.73 feet, and the gauge on the curve is 4.736 feet, the inner rail being again set out; on curves of 590.4 feet to 1,312 feet radius, the outer rail is set out to give a gauge of 4.75 at the end of the curve, and is set out again to give a gauge of 4.762 feet on the curve. This method enables very close adjustments to be made, and the gauge is accurately maintained, but it has the disadvantage of requiring the use of several different kinds and sizes of material in track work, and as the fastening of each rail to each tie requires four separate pieces (three gibs and one cotter) the result is an apparant complication, especially on a line having many curves, where different sizes of gibs are required. On the other hand, fastenings used with metal ties are expected to require very much less attention when once in place than fastenings used with wooden ties, and many bolt fastenings require a still greater number of pieces. In track work it is always desirable to have as few separate pieces and as great simplicity as possible.

The following particulars are taken from the company's book of "Instruction for the laying and ballasting of track having rails 39.36 feet long," issued in 1885:

The gauge of the road is 4.70 feet on wooden ties and 4.71 feet on metal ties. The rails are of flange section, weighing 66.40 pounds per yard; they are 5.08 inches high with a head 2.4 inches wide and a flange 4 inches wide; they have an inward inclination of 1 in 20. The joints are square and suspended, and are spliced by fish plates with four bolts; some of the plates have a lug which bears against the tie plate on wooden ties, or against the gib fastening on metal ties, the object being to prevent creeping of the rails. Changes of grade are effected by a vertical curve of 3,280 feet radius, giving a deflection of .32 inch for a rail length of 39.36 feet. The following spacing of ties for rails of this length was adopted in 1887: Wooden ties are spaced 24.8 inches apart at the joints, 29.2 and 32.8 inches next to the joints, and 36.8 inches for intermediate ties; metal ties have the ties at the joints spaced 20 inches apart, center to center, the next ones 30 and 34.4 inches, and the intermediate ties 36.8 inches apart. The width at subgrade for single track is 16.40 feet. With wooden ties the ballast is 14.8 inches deep at the middle, 16.8 inches deep at the sides, and 9.84 feet wide on top for single track; the subgrade is crowned, and the surface of the ballast is horizontal, just covering the ties. On curves the top of the ballast is given the same slope as the ties and on double track on curves the ballast between the two tracks is rounded off to a level with the top of the tie of the inner track and the top of the rail of the outer track. With metal ties the arrangement is similar, but the ballast is shallower, only level with the tops of the ties and not covering them; it is only 8.2 feet wide on top for single track. The volume of ballast per yard single track is as follows, the volume of the ties being deducted where wooden ties are used:

	With wooden ties.	With metal ties.
	Cubic yards.	*Cubic yards.*
On tangents	1.55	.83
On curves below 1,968 feet	1.71	.79

In April, 1888, Mr. Mayer, chief engineer of permanent way, stated that the laying of these ties was commenced in 1883; up to the date of his letter 52.70 miles had been laid, and 21.7 miles were to be laid during 1888. Some of the ties put down in 1883 were taken out in 1888 to see how they had behaved in service, and they were found to be in excellent condition. They weigh, he stated, 96.8 to 99 pounds each. The track keeps in good order, and the engineer was very well satisfied with the ties. The cost of maintenance was even more economical than with wooden ties. It is expected that these ties will last twice or two and a half times as long as the best oak ties; when rejected they will always be worth 40 to 50 cents each, while rejected oak ties are not worth more than 8 to 10 cents each. They are made from mild steel plates, and the railway pays $26.40 per ton of 2,200 pounds, or $1.16 per tie. An oak tie costs $1, and the two iron tie-plates for the same cost 10 cents. The ballast used with the metal ties consists of screened gravel, not too coarse, broken to pass through a ring of 1.6 inches diameter; broken stone of the same size is also used.

At the meeting of the International Railway Congress, at Paris, in 1889, Mr. Mayer presented the following information:

Since 1883 metal ties have been used in regular service, being introduced gradually as the wooden ties necessitate renewals. The total length of track thus laid is as follows:

	Miles.
1883	6.738
1884	10.725
1885	10.131
1886	9.512
1887	13.036
1888	18.426
Total at end of 1888	68.568

This represents a total of about 126,990 ties in the track. The work is being continued, and it is intended to lay about 15.5 to 18.6 miles of metal track per year. Contracts have been made for supplies for five years. This type of track, as already described, is now adopted as the standard track of the road. The ties first used were of uniform section throughout, but the form adopted in 1887 is narrow and deep at the middle (See plate No. 15); the objects being to give a better hold on the ballast, to increase the stiffness of the tie, and to prevent lateral motion of the tie. The ties are of mild steel, having a resistance to breaking of 56,000 to 65,000 pounds per square inch. The weight is 99 pounds per tie.

The maximum grades are 2.3 per cent. and the minimum radius of curves is 1,148 feet. The traffic varies on different parts of the line, being from eight trains in each direction per day, with a maximum speed of 28 miles per hour, on branch lines, to thirty trains in each direction per day, with a maximum speed of 40 miles per hour, on the main line. The heaviest locomotives weigh about 34 tons, with a maximum load of 12 tons on an axle, though some of the old four-wheel tank engines still in use have a load of 13 tons per axle. Up to 1884 the rails were 19.68 feet long, with seven ties to a rail length. They are now made 39.36 feet long, with thirteen, or in exceptional cases fourteen, ties to a rail length. The first cost of track on new wooden ties is about $47 per rail length, or about $3.58½ per yard. The first cost of track on steel ties is about $47.55 per rail length, or about $3.62½ per yard. The current prices, on which these estimates were made, were 87 cents each for oak ties and $1.31 each for steel ties ($1.16 for the tie and 15 cents for the fastenings). The cost of maintenance has not yet been established, but reports for the year ending

February, 1889, for twenty-two sections of track on steel ties and twenty-one sections of track on wooden ties, showed the maintenance expenses of the former to be slightly less than those of the latter. The company has found, and this is the general experience, that the maintenance expenses of track on metal ties are during the first two years rather higher than those of track on wooden ties, but after that time they decrease considerably for the former. The introduction of steel ties has reduced the price of oak ties from $1.25 to 87 cents each. A slight but scarcely perceptible metallic sound is heard when traveling over the steel ties. No difference in the wear of the rolling-stock has been noted. A few fastenings have been renewed, not on account of failure, but because they were considered to be too light, and were replaced with others of stronger make. The durability of the steel ties has not yet been determined, but those first put down in 1883 do not show any wear or cutting by the rail flange. Of the 126,990 steel ties laid, only 43 have been taken out on account of breakage (0.03386 per cent.), while it is estimated that with the same number of wooden ties the renewals would have amounted to 20,000 or 25,000 ties (15.75 to 19.7 per cent.).

JURA, BERNE AND LUZERNE RAILWAY.—Iron cross-ties are in use on this road, and the following statement in regard to the track was sent to me in August, 1889, by the chief engineer:

	Inclusive of the Bodeli and Brunig lines.	Exclusive of the Brunig line.
	Miles.	*Miles.*
Total length of road	216.24	188.44
Length in operation	228.16	200.26
Length of track:		
With wooden ties	229.31	223.09
With metal ties	33.04	7.95
Total length of track	262.35	231.04

The ties are of iron and are of a somewhat similar type to those used on the Gotthard Railway, but the cross-section at the rail-seat more closely resembles the "Post" tie (See "Holland"), with a rib on each of the lower edges. The tie is 7.87 feet long; at the outer part of the rail-seat it is 4 inches wide on top, 9.4 inches wide over the ribs at the bottom, and 3.56 inches deep; at the inner part of the rail-seat it is 4.8 inches wide on top, 9.4 inches wide on the bottom, and 2.8 inches deep; at the middle it is of ∩ section, about 3.5 inches wide and 5.36 inches deep. The thickness of the sides is from .24 inch at the bottom to .32 inch at the top; the top table is .28 inch thick, except at the rail-seat, where it is .44 inch thick; the ribs on the edges are about .72 inch deep. The inclination of the rail seat is 1 in 20. The rails are secured by bolted clamps on the Ruppel system (See plate No. 13), the adjustment of the gauge being effected by the use of different sets of clamps.

On the Delle and Basle line a length of 1.55 miles has been laid with a rather different form of track, designed by Mr. Bieri, an engineer on this road. The rail rests on a tie-plate which gives it the inclination of 1 in 20; bolted clamps of ⌐ shape hold the rail flange, but the vertical leg does not fit into the bolt-hole. A hole in the middle of the tie-plate is over a smaller hole in the tie, and into these holes fits a metal plug of T section; the width of the projection of the head is different on each side, the leg not being in the middle, so that by turning the plug the position of the tie-plate, and consequently the gauge of the track, is altered. This is a somewhat similar plan to that tried in India by Sir Guilford L. Molesworth, consulting engineer for state railways, but in that case the plugs were used in cast-iron bowls and the legs engaged with notches in the tie-bars. On the Delle and Basle line there are twenty-nine trains per day besides a number of extra trains (often one or two per day) during the months of busiest traffic.

UNITED SWISS RAILWAYS.—In August, 1889, the chief engineer stated that on this line, which is 166.16 miles long, 1,843 mild steel ties were laid during 1887 and to the end of 1888. These ties were similar to those of the Gotthard Railway (See plate No. 15). They were manufactured at the Good Hope Works and the Hoerde Works, and cost $28.40 per 2,200 pounds, or $1.64 each. The ties are 8.2 feet long, and are narrow and deep at the middle; at the rail seat the cross-section is 4.8 inches wide on top, 9.28 inches wide over the ribs on the bottom edges, and 3.4 inches deep; the top corners have a radius of 1.6 inches, and the sides have an outward slope of 5 to 1; the thickness of the top table is .48 inch and of the sides .28 inch. Inside the rail seat the cross section is similar, but only 3.24 inches deep, and the thickness of the top table is .32 inch. At the middle it is of ∩ section, 2.54 inches wide on top, with top corner curves of .88 inch radius; depth 5.52 inches; width inside at bottom, 3.46 inches. The weight is 127.6 to 134.2 pounds. The bolt holes are .84 inch square, with rounded corners. For rails 39.36 feet long, there are fifteen ties; the joint ties are spaced 21.6 inches apart center to center, the ties next to the joints 26.4 inches, the next 30.08 inches, and the intermediate ties 34.4 inches. For rails 29.52 feet long there are twelve ties; the joint ties are spaced 21.6 inches, the next 26.4 inches, the next 28 inches, and the intermediate 32.8 inches. For rails 19.68 feet long, there are eight ties; the joint ties are spaced 21.6 inches, the next 26.8 inches, the next 30.8 inches, and the intermediate ties 34.4 inches. The rail joints are square, suspended, and are spliced by angle-bars 26.8 inches long, extending over the joint ties and having the flanges notched for the rail clamps on the ties; the bars weigh 22.66 pounds each, and have four bolts. The rail fastenings are of the Roth-and-Schuler type (See plate No. 13); the bolts are .76 inch diameter, with a round head and a neck .8 inch square; the gauge washers are 1.76 inches square, with a hole .8 inch diameter so placed as to be .28, .38, .58, and .68 inch from the sides, allowing for the adjustment of the gauge of the track. A channel-shaped rail clamp with an oval bolt hole, .84 by 1.24 inches, fits over the washer, one leg resting on the rail flange and the other on the tie. The bolt passes through the tie, washer, and clamp, and the nut is screwed down on the latter.

The engines used have four coupled wheels, and weigh 110,000 pounds. The maximum grades are 2 per cent. and the sharpest curves are of 721.6 to 984 feet radius. No experience had then been acquired as to the cost of maintenance; the short time of observation had showed that the wear of the ties is small, but that the wear of the bolts and the gauge washers is considerable on the sharp curves of 721.6 to 984 feet radius with this (Roth and-Schuler) system of fastening. The ballast is of gravel, and is 16 inches thick under the ties. The rails are of flange section, weighing 74.43 pounds per yard. The steel ties were adopted because the neighboring roads have had satisfactory experience with them, and because the price of oak ties rose while that of steel remained cheap. It seemed, however, at the time of writing (August 1889), that the price of steel would also go up. Oak ties, 7.87 feet long by 9.6 inches by 6 inches, cost about $1.12 to $1.20 each, and have an average life of seventeen years. Larch (or tamarack or hackmatack) ties of the same dimensions cost 66 to 80 cents each, and have an average life of ten years.

SWISS CENTRAL RAILWAY.—Metal ties were first used about 1880; they are of the "Berg-and-Mark" type (Germany), resembling those in use on the Western and Simplon Railway (See plate No. 15). They are 7.87 feet long; the first ones used weighed 103.4 pounds each, but the later ones weigh 118.8 pounds. The gib and cotter fastenings are used. The earlier ties were of iron, the later ones are of steel. At the end of 1884 there were over 100,000 ties in service, and it was intended to lay about 30,000 per year until they had been laid over the entire system. The engineers were well satisfied with the results obtained, and they considered the track more elastic than track on wooden ties. The cotters are said to keep tight and do not wear the holes. At switches heavier ties are used, with the top table .52 inch thick, the purpose being to have them strong enough not to be broken by derailments, which occur more frequently at switches than on the open track. The ballast is of round, clear gravel, and forms a core in the tie. The engineers have found by experience that the metal ties require a better ballast than the wooden ties, but that when well settled, and after the first year of maintenance, one packing of the ballast each year is sufficient to keep the track in good condition. Mr. Bricka, in his report, (1885) gives the following statement of the track for 1884:

	Miles.
Main line	244.28
Total track	403.62
Wooden ties	333.56
Metal ties	70.06

MOUNT PILATUS RAILWAY.—This is a rack railway up Mount Pilatus. It is about 2¼ miles long, and has a maximum grade of 48 per cent. The rack is a flat steel bar with teeth on each side, and the driving or spur wheels of the engines are horizontal. The track is entirely of metal, and the ties are bolted down to the masonry substructure by bolts 1.08 inch diameter. The cross-ties are of channel section, inverted; they are 4 feet long, 5.6 inches wide, and 2½ inches deep. The joint ties are spaced 15.2 inches apart and the intermediate ties 4.3 feet. In the middle of each tie is a chair built up of an inverted channel 10.2 inches wide and 2.88 inches deep, with an angle-iron 2.40 by 2.40 inches at each side, the angle-irons being riveted to the sides of the chair and the top of the tie by two rivets on each side. At the joints the chairs extend over the two joint ties, being 20.8 inches long. These chairs carry an iron longitudinal of approximately ⎍ section, 8.4 inches wide, 4 inches deep, and on top of this is bolted the flat rack-rail, which is 5.2 inches wide over the teeth and 1.6 inches deep, made in sections 9.84 feet long. The gauge of the track is 32 inches. The rails are of flange section, about 4.8 inches high, with a head 1.64 inches wide and a flange 4 inches wide; they are 19.68 feet long. The rail joints are secured by angle-bars bolted in the usual way. The bars are 2.72 inches high, with a flange 3.2 inches wide having a rib on the underside of the outer edge of the flange. This rib bears on the tie while the flange bears on the rail. Each angle-bar is bolted to the tie and extends over the two joint ties; a short angle-bar fastening is used at each intermediate tie. The rails and rack are laid to break joint, so that each rail has two ties close together at the middle. The horizontal curves have a radius of 262.4 feet (about 22 degrees), the vertical curves, at changes of grade, have a radius of 1,640 feet.

BURGENSTOCK RAILWAY.—This is a short rack railway, on the Abt system, up the Burgenstock mountain. It is operated by a cable, the plant being driven by electricity generated by water power at a considerable distance; the rack gear is intended merely for safety, on account of the steep grade. The line is 3,070.08 feet long, with a grade of 32 per cent. for 1,148 feet from the bottom and 58 per cent. for the remainder of the distance. It is the steepest railway in existence. At the middle of the line is a curve 606.8 feet long, the tangents of which form an angle of 112 degrees. The cross-ties are angle-irons about 4.92 feet long; the vertical web is about 3.2 inches deep, and is imbedded in masonry; the horizontal web is about 4.8 inches wide and carries the rails. The gauge is 1 meter. The rails are of flange section, weighing 44.25 pounds per yard; they are 4.6 inches high, with a flange 3.96 inches wide, resting on a plate .20 inch thick between the rail and tie. The rails are fastened by bolted clamps, or by bolts passing through the rail flanges. The ends of the ties are closed by riveted angle-irons. In the middle of the track is a rack-rail of two bars, .8 inch thick and 1.12 inches apart, each bolted or riveted to an angle iron bolted to the tie.

SUMMARY OF METAL TRACK FOR SWITZERLAND.

Railways.	Longitudinals.	Cross-ties.	Total.
	Miles.	*Miles.*	*Miles.*
Gotthard	.25	37.00	37.25
Northeastern		41.00	41.00
Western and Simplon		68.57	68.57
Jura, Berne, and Lucerne		33.04	33.04
United Swiss		1.00	1.00
Swiss Central (estimated)		120.00	120.00
Mount Pilatus		2.75	2.75
Burgenstock		.62	.62
Total (compiled from returns)	.25	303.98	304.23
Actual total in 1889			397.40

SPAIN.

GENERAL REMARKS.—In Spain, metal ties are in use to a moderate extent, but wooden ties, either of native fir or imported creosoted pine, are more generally used. In October, 1888, the following interesting statement from a Spanish correspondent was published in an English technical paper:

> Very large quantities of the fir ties used by Spanish railways have been derived from the forest districts of Portugal north of Oporto. I have lately been visiting this district, and find that in places where, twenty-five years ago, fir trees of sufficient size for ties seemed innumerable, there are hardly any to be seen now which could be used for that purpose within twenty years. Espinho, Caminha, and Vianna, which are small ports from which the ties used to be shipped, have now scarcely any traffic of this kind at all. Considering that Spain may require within a comparatively short period 20,000,000 or 30,000,000 of ties for new lines, besides those required to replace decayed wooden ties on the existing lines, there can be very little doubt that steel ties will rapidly come into use in this country.

The gentleman whose statement is quoted above wrote to me in January, 1889, saying that the principal railway companies were still using wooden ties, of which a great number came from the north of Europe, and some from the Landes, in France. Prices have not been altered for some years, but in the country large timber for ties is very scarce. At one time he imported 1,000,000 ties from Portugal, but in 1887 he went over the district where the trees had been cut and found that it would be many years before other ties could be obtained from there. In the north of Spain, particularly toward the Pyrenees, oak ties are still to be had, but even for the lines decided to be constructed this source of supply will not be sufficient. He thinks the period is fast approaching when metal ties will be a necessity. In September 1889, the same gentleman stated in a letter to the paper above mentioned that although a scarcity of wood for mining purposes was being felt in Asturias, wooden ties were being sold in other parts of the country at cheaper rates than had ever been known before.

The maximum life of Spanish pine ties, not creosoted, is reported as about five years. On the Rio Tinto Railway, creosoted Baltic ties are found more economical, lasting ten or twelve years.

During the discussion of a paper on "Metal Sleepers for Railways," by Mr. E. Benedict, read before the Institution of Engineers and Shipbuilders, Glasgow, in March, 1877, Mr. Peter Stewart stated that he had some experience on a short line in the south of Spain, half of which, or about 14 miles, was laid with rectangular cast-iron bowls, with tie-rods, in sand ballast. The rest of the line was laid with uncreosoted wooden ties. In running over the road there was a hard metallic ringing sound from the iron track. This portion of the line was very favorable as regarded grades and curves, but the difficulty and cost of general maintenance were so great that the iron ties had to be replaced with wooden ties, which, with ordinary care, were little affected by the climate, and gave very fair results.

Much interest in the subject of metal ties is said to be shown at Bilbao, that place being an important center of the iron industry. It was hoped that the Northern Railway would adopt cast-iron ties, as the productive capacity of the iron-works exceeds the demand for home consumption, but so far oak ties appear to be preferred.

BILBAO AND LAS ARENAS RAILWAY.—This line runs from the port of Bilbao to the town of Las Arenas at the mouth of the river; it is 7.10 miles long, one meter gauge; minimum radius of curves, 278.8 feet, and 360.8 feet maximum grade, 1.98 per cent. The main line and sidings are laid with steel cross-ties which were put down in June, 1887. (See plate No. 16.)

In a communication received in May, 1888, in regard to this line, it was stated to be believed that these ties would be cheaper than wooden ties. At first more attention has to be paid to such track than that laid on wooden ties. No difficulty had been experienced with the fastenings. The gauge had been maintained better than is possible with wooden ties. It was, however, considered advisable to increase the length of the ties and to space them more widely apart on any extensions of the line. The ties are of inverted trough section, being of the modified Vautherin type, with a rib on each of the lower edges. They are 4.92 feet long, 3.6 inches wide on top, 7.2 inches wide at the bottom, 2.4 inches deep. The thickness of the sides is .24 inch, of the rib .52 inch; the top table is .26 inch, but with a rib on the underside increasing the thickness at the middle to .32 inch. The tie is horizontal throughout except that the rail seats have an inclination of 1 in 17 for a length of 6.20 inches, and are then sloped down to the normal level. At each rail seat there are two rectangular holes, 1.64 inches long by 76 inch wide, 2.4 inches apart in the clear. The fastenings are on the Ruppel plan (See "Germany; Left-Bank of the Rhine Railway"), and consist of clamps which hold the rail flange and have a lug projecting downward and fitting into the bolt hole in the tie; these clamps are secured by tee-headed bolts, the heads being inside the tie, and the nuts screwing down on the clamps. The joint ties are placed 16.48 inches apart, center to center, and the intermediate ties are spaced 35.44 inches apart on tangents and 31.2 inches on curves. They were manufactured at the Bochum Works, in Germany, and were not painted or otherwise treated. The rails are of flange section, weighing 32.16 pounds per yard; they are 3.6 inches high, with a head 1.6 inches wide and a flange 3.8 inches wide. The rail joints are suspended, and are spliced by straight fish plates of curved section, fastened by four tee-headed bolts; the plates are 14.4 inches long; the inner holes are 4.56 inches apart, center to center, and the outer holes 3.28 inches. The ballast is of broken stone, which becomes pulverized. The weight of the locomotives is about 20 tons.

Another statement, received in January, 1889, gives the following particulars:

> The ties were laid in 1886 under the supervision of Don Adolfo Ibarreta; they are 4.6 feet long on tangents and 5.25 feet long on curves, and are spaced 21.6 inches apart on curves and 25.6 inches on tangents. They are of mild steel, weighing 46.2 pounds each, and cost about 75 cents each. The ballast is of broken stone, of a rather soft character; it behaves well under the ties if the pieces do not exceed 2 inches in size. The rails weigh 34.2 pounds per yard. The traffic consists principally of passenger trains, and the engines, with six wheels, weigh about eighteen tons. The reason for adopting these ties was that wooden ties have a short life, owing to the wet nature of the ground; they have proved generally satisfactory, and the bolt fastenings hold much better than the spikes in wooden ties. There has been no trouble from breakage, and no difficulty with rail attachments or maintenance. The ties would have given better satisfaction if they had been heavier. The steel ties are considered to be very well adapted for use in wet climates, but track on metal ties takes some little time to settle down to a firm and permanent bearing. Wooden ties would have cost about 50 cents each, but none have been used on this line.

ALMANSA, VALENCIA AND TARRAGONA RAILWAY.—This line is 251.68 miles long, with a gauge of 5 feet 6 inches; the gauge is uniform on tangents and curves. The maximum grade is 1.55 per cent., and the minimum radius of curves is 583.84 feet. Cast-iron plate ties of the DeBergue system are used. (See plate No. 16.) They were laid between Valencia and Tarragona in 1860, and in 1873 they were laid on the line between Almansa and Valencia. The traffic is mixed, principally freight; and the trains are hauled by engines weighing about 50 tons, with tenders weighing 25 tons, in working order.

The ties consist of cast-iron plates arranged in pairs and connected by tie-bars; they were made in England and cost about 69.6 cents for each plate and 50.3 cents for each tie-bar. No paint or preservative is used. The plates are laid 34 inches apart, center to center of each pair, but the tie-bars are only put in every alternate pair. (This practice was originally followed on some of the railways in India, but after some experience tie-bars were put in for every pair of plates.) The cost of maintenance is about $3.77 per mile per year, including labor and material. The life of a pair of plates and a tie-bar is twenty years. This track is found more economical, and the gauge is maintained better than with timber ties. No difficulty is experienced with maintenance, and breakages only occur where plates are changed while trains are running.

The climatic effects upon the metal ties are inappreciable, but they have a material effect upon timber ties. The rails are of Bessemer steel, weighing 63.30 pounds per yard, and having suspended joints fastened by four bolts. They are of flange section, 4.52 inches high, with a flange 3.28 inches wide, and a head 2.48 inches wide; the head is rounded, top table 4.52 inches radius, top and bottom corners .52 inch radius, with a vertical strip about one-eighth inch deep between them; the flange is narrow but very thick, the top faces being at a steep angle. The ballast on single track is 10.82 feet wide on the top, 14.46 feet at the bottom; the width at subgrade is 16.9 feet in cuts and 19.68 feet in fills. In cuts there is a ditch on each side of the track 28 inches wide on top, 5.6 inches wide at the bottom, and 10.92 inches deep. The ballast is 16.8 inches deep, and average 1.107 cubic yards of gravel per linear yard.

Each plate is rectangular in shape, 19.6 inches long with the rail, 15.2 inches wide, with rounded corners. The bottom is flat, with a shallow rib along the middle, in the direction of the rail, having an opening at the middle of the tie-bar; a lug on the bottom of the plate engages with a notch in the top edge of the tie-bar. On the top of the plate are two longitudinal ribs, with four transverse ribs between them; these transverse ribs are not so high as the two longitudinal ribs, and are inclined so as to give the rail its inward inclination. A shallow rib runs round the edge of the plate, and four curved webs or fillets connect with the longitudinal ribs. The outer flange of the rail rests against the inner side of the rib, but is not held down; the inner flange is secured by a clamp which rests on the plate-rib and the rail flange and is fastened by a hooked bolt, the tie-bar resting in the loop and the nut being screwed on from the top, bearing on the rail-clamp. Each plate weighs 63.8 pounds. The tie-bar is 6.36 feet long, .52 inch thick, and 2.8 inches deep, weighing 28.6 pounds. It is placed edgeways under the plates, a notch at each end engaging with a lug on the bottom of the plate so as to insure the accuracy of the gauge, and it is held in place by the **U** bolts.

SUMMARY OF METAL TRACK FOR SPAIN.

Railways.	Bowls.	Cross-ties.	Total.
	Miles.	*Miles.*	*Miles.*
Bilbao and Las Arenas	.. ..	7.10	7.10
Almansa, Valencia, and Tarragona	251.68	....	251.68
Total	251.68	7.10	258.78

PORTUGAL.

ROYAL RAILWAYS.—At the International Railway Congress, held at Milan, Italy, in 1887, Mr. Kowalski stated that forty pieces of the MacLellan system (See "England") had been put down as an experiment, but the trial had been too short for any conclusions to be drawn.

ITALY.

General Remarks.—The railways in Italy are owned by the state, but are leased to operating companies under government supervision. The railways are divided into two main systems, the Adriatic system and the Mediterranean system, each operated by a separate company.

Metal ties have not yet been introduced except in a very small way for experiments, as oak ties can be obtained at a much lower price, 80 cents to $1 each. It is probable that the extension of the railway systems and the increasing destruction of oak trees will change this state of things eventually, but the time is in the distant future, as the growth of the railways is not rapid or extensive. It was at one time reported that the Mediterranean Railway Company proposed to introduce metal ties upon one of its divisions, at an estimated cost of about $115,200, but this report has not been confirmed, and in answer to an inquiry the engineer merely replied that metal ties are not used. The director general of the Adriatic Railway Company stated, in May, 1889, that metal ties have not been used on the lines operated by that company; he stated further that the use of such ties is not advisable for the present, because the difference in cost of metal and wooden ties is considerable, and he does not think they will be adopted in the near future, as the Italian forests will furnish very good timber for many years yet.

A few steel ties of the type used on the Northeastern Railway, England, have been imported for experimental trial. The Italian Government has laid steel ties on about 13 miles of the line from Massana to Sahati, in Africa, and particulars of these will be found under the heading of Africa.

According to information sent me in May, 1888, by an engineer connected with one of the technical papers of Italy, there are a great many short old lines of railway, the greater part of which have been united to form four principal systems. Renewals have not been carried out as fast as was desirable, and therefore there were a great number of different tracks, old and new. In May, 1888, a commission, composed of representatives of the more important railway companies, proposed to the secretary of state for public works a new type of track, to be adopted gradually in renewals. Its principal features were as follows: Steel rails of flange section, 39.36 feet long, 5.2 inches high, 4.4 inches width of flange, 2.56 inches width of head, .56 inch thickness of web; weight, 76.45 pounds per yard. Suspended joints, spliced by angle-bars with four bolts. There were to be thirteen or fourteen wooden ties to a rail length, and the rails were to be fastened by screws. Tie-plates of iron, 7.6 inches by 6 inches and 7.6 inches by 7.2 inches, .6 inch thick, were also to be used. This project was examined by the superior council of public works, which decided that under existing circumstances, considering chiefly the money side of the question, it was not advisable to adopt a new form of track.

SWEDEN AND NORWAY.

GENERAL REMARKS.—The only trial made with metal ties in Sweden or Norway has been for a short distance on the Swedish state railways, a description of which trial is given herewith.

The following general information relating to the railways of these countries is taken from a communication received in May, 1888, from Mr. John Johnson, manager and engineer of the Swedish Central Railway:

> Timber ties, unpreserved, are generally used; they are principally of fir, with a small proportion of oak in the south of Sweden; for standard gauge lines they are 8.75 feet long, 9 inches wide, and 6.4 inches thick; fir ties have an average life of 10 to 12 years, and cost 27 to 30 cents each. The rails are of steel, of flange section, and are of the C. P. Sandberg standard patterns, weighing 56.5 to 60.36 pounds per yard for the standard gauge, and 30.10 to 34.2 pounds per yard for narrow-gauge lines. The rails are fastened direct to the ties by spikes 5.4 inches long, and no tie-plates are used. The rail joints are suspended, the joint ties being placed only half as far apart as the intermediate ties. The rail joints are spliced by two angle-bars each, or one straight and one angle bar. There are nine ties to a rail length of 23.94 feet. The ballast is usually of gravel, and blast-furnace slag is used where gravel is scarce; it is laid flush with the top of the ties, and is 12 to 14 inches deep. The mileage of the railways in 1888 was as follows: Sweden, 1,547.52 miles of government lines and 3,025.60 miles of private lines; all the former are of standard gauge (4 feet 8½ inches), but 908.92 miles of the latter are of gauges varying from 4 feet to 32.08 inches. There are only 1.86 miles of double track. Norway, 968.44 miles, of which 926.28 miles are owned by the government and 42.16 miles by a private company. The government lines include 324.88 miles of standard gauge and 601.40 miles of 3 feet 6 inches gauge. The private lines are of standard gauge. All the lines are single track.

SWEDISH STATE RAILWAYS.—In June, 1888, Mr. Storckenfeldt, assistant chief engineer of the state railways, sent me some information in regard to experiments made on a small scale on this system of railways, and notes of these experiments were presented at the International Railway Congress held at Milan in 1887. Up to July, 1887, the trials had been in progress for eleven months. The ties are of the "Berg-and-Mark" type. They are placed for a length of 2,645.6 feet near the station at Akarju; they are on a tangent, with a grade of 1 in 147; part of the track is in a cutting and the remainder is on embankment. The traffic averages twenty freight and passenger trains per day; of these, four are freight trains with an average of forty cars, weighing 610 tons loaded, and sixteen are mixed and passenger trains with an average of fourteen cars, weighing 264 tons loaded. The speed varies from 30 to 34 miles per hour for express trains, 34 miles per hour for mixed trains, and 25 miles per hour for freight trains. The weight of locomotive and tender is about 43 tons.

The ties are of iron, of the original "Berg-and-Mark" type (see Plate No. 12). They are 7.54 feet long, 5.2 inches wide on top, 9.2 inches wide on the bottom, and 2.4 inches deep, with the sides vertical 1 inch from the bottom. The thickness of the sides is from .24 inch at the bottom to .28 inch at the top; the top table is .36 inch thick, with a rib in the middle on the underside increasing the thickness to .52 inch for a width of 1.44 inches. They are of uniform section throughout their length. The middle part is horizontal for a length of 3.28 feet, and the ends are bent up at an angle of 1 in 20. The ends are closed by bending down the top table. At each rail seat there are two holes 1.72 by .84 inch, and 3.42 inches apart in the clear. The tie itself weighs 95.91 pounds, the attachments 2.61 pounds, and the bolts, nuts, and washer 2.68 pounds, making a total weight of 101.20 pounds per tie. They were manufactured by the Union Iron and Steel Company, of Dortmund, Germany. The rails are of steel, of flange section, and the fastenings are bolted clamps on the Ruppel plan (see Plate No. 13). The ballast is of poor quality, being composed of a mechanical mixture; 30 per cent. of broken stone, 27 per cent. of gravel, 38 per cent. of coarse sand, and 5 per cent. of fine sand, clay, and particles of soil. The ballast is poor even from a mineralogical point of view as it contains among other kinds of disintegrated rock 8 to 9 per cent. of burned limestone, or the refuse from the lime kilns.

The metal ties were laid as an experiment to test their advantages under the conditions prevailing in this country. The cost of track laying and of maintenance were about the same as with wooden ties. In regard to the durability of the tie and the fastenings it was stated that the fastenings of the rails to the ties had remained in good condition. This track does not appear to have a bad effect upon the rolling stock; the elasticity of the track is good, and no complaints have been made by passengers as to any discomforts in traveling over it. While the trials, up to July, 1887, had been satisfactory, the following recommendations were made: The ties should be a little longer and deeper, as it has been found that they do not offer sufficient stability, and the track has to be put in condition as to line and surface several times. No relations were established between the price of wooden and metal ties, on account of the short time since the latter had been put in.

DENMARK.

General Remarks.—In this country there are 996.34 miles of railway owned by the state and 250.40 miles owned by private companies; they are all of standard gauge and all single track with the exception of 27.9 miles. The rails are of steel, of flange section; on the main lines the weight is 62.88 pounds per yard, but on secondary lines it is only 44.87 pounds, and on one line it is only 35 pounds per yard.

Danish State Railways.—April, 1888, I received a communication from the general director of state railways in regard to experiments made with metal ties. On the line from Tommerup to Assens (island of Fiona or Funen) there is a length of 18.1 miles laid with cross-ties of Martin mild steel. The ties were laid in 1883-'84, under the supervision of Mr. O. Hoyer, engineer. On this division 34.73 per cent. of the length is level, 4.95 per cent. has grades of 1 in 1,000 to 1 in 200, and 60.32 per cent. has grades of 1 in 200 to 1 in 100. As to curves, 73.54 per cent. of the length of the division is straight, 24.19 per cent. on curves of more than 1,640 feet radius, and 2.27 per cent. on curves of 1,640 feet radius and less. The traffic consists of eight trains daily (passenger and freight). The locomotives weigh 17.9 tons each, with 9 tons on the driving wheels.

The ties are of inverted trough section; they are 7.2 feet long, 3.2 inches wide on top, 7.2 inches wide on the bottom, and 2.4 inches deep, with the sides vertical for .8 inch from the bottom. The thickness of the sides and top is .24 inch, with a rib 1.6 inches wide on the under side of the top table, increasing the thickness to .32 inch. Each end is closed by a riveted angle piece, and two cross pieces are riveted inside at about one-third of the length from each end. The section is uniform throughout. The ties are horizontal at the middle for 4.26 feet, then inclined up at an angle of 1 in 20 for 8 inches at the rail-seat, and then again horizontal for 10 inches to the end. At each rail-seat there are two rectangular holes 1.56 by .84 inch, and 3.22 inches apart in the clear.

The fastenings are of the Ruppel plan (see Plate No. 13); they consist of two clamps holding the sides of the rail flange, and having a lug fitting into the hole in the tie. A bolt .76 inch in diameter passes up through the tie and clamp and the nut is screwed down on the clamp. The bolt has a tee-head .76 by 1.4 inches, inside the tie; the part in the hole in the ties is of circular section, but the part in the hole in the clamp is rectangular, .76 by .96 inch. The clamps are 2.4 inches long and their bolt holes are .82 by 1.04 inches. The adjustment of gauge at curves is effected by the use of clamps of different sizes. The ties are manufactured by the Union Steel and Iron Company, of Dortmund, Germany; they weigh 53.28 pounds each and cost $38 per 2,200 pounds. They are tarred at the works. The experience has been insufficient for information to be given in regard to durability, cost of maintenance, and efficiency as compared with wooden ties. The rails are of flange section, 3.8 inches high with a head 2.16 inches wide and a flange 3.42 inches wide; the weight is 45 pounds per yard. They are 21 feet long and there are 8 ties to a rail length, spaced 18.4 inches apart, center to center at the joints with the next ties 32.52 inches and the intermediate ties 34.52 inches apart. The rail joints are square, suspended, and fastened by angle splice bars. The width at subgrade is 15.41 feet; width over bottom of ballast-bed, 13.45 feet; the ballast is 8.4 inches deep under the ties; at the middle and ends it is 3.2 inches deep over the ties, sloping down to the rail flanges. The ballast is of gravel.

These metal ties were adopted for experiment, and the general results have not been quite satisfactory. There was trouble with the maintenance, frequent lifting of the track being necessary. Breakages were rare and occurred generally at the hole for the outer bolt and clamp. The weight and strength of the tie were reported to be insufficient. When the gravel bed under the ties is frozen, water is retained in the interior of the ties, and during the passage of trains water and gravel spurt through the holes in the ties and cover the rails and wheels.

The wooden ties used are of Pomeranian fir (pine), costing $6.30 to $6.97 per cubic meter in 1888. They last from eight to ten years. The climate is about the same as in Germany.

RUSSIA.

General Remarks.—Metal ties have been tried in this country on a very small scale. In May, 1888, General Possiet, then minister of ways and communications, stated that they had only been used to a very limited extent on two branch roads; these were the Kursk-Kiev road and the Donets road, and even there they had not been sufficiently used to enable him to give any conclusions respecting them.

Mr. Hugh Carlile, chief engineer of the Dunaberg-Witepsk Railway, stated in February, 1888, that good red pine ties, 9 feet by 10 inches by 6 inches, would be obtained at about 40 cents each. A difficulty which would be met with in the part of Russia traversed by this railway in using metal ties would be in repairing the track for frost blisters in winter, which is usually done by inserting wooden wedges or packing between the rail and tie ("shimming," as it is termed in American railway track-work), the wedges being spiked to the ties to prevent them from moving.

Moscow-Kursk Railway.—Some metal ties were laid on this line, but were taken up again, as they proved too expensive in maintenance, so it is said; their maintenance being more expensive than that of wooden ties. In the spring and fall seasons especially the cost of surfacing was found to be much higher than with wooden ties. The cost of iron being greater and that of wood being less in Russia than in some other European countries, it was claimed that at the prices of material in 1888 the iron ties cost one and a half times as much as oak ties not treated, and two and a half times as much as pine ties treated with chloride of zinc. The basis of comparison was a life of thirty-five years for iron ties weighing 112 pounds, and a life of ten years for treated and six years for untreated wooden ties. Conditions in Russia, however, are exceptional as regards material and labor.

TURKEY.

Eastern Railways.—The following particulars were presented by Mr. Kowalski at the International Railway Congress, held at Milan, Italy, in 1887:

> The track laid with metal ties comprised 61.38 miles on which the ties were adopted for regular service, and 9.3 miles on which the ties were laid for experiment. The ties were of mild steel, and were of two types, viz, the original "Vautherin" type,

with horizontal flanges on the lower edges, and the original "Berg-and-Mark" type (see plate No. 12). They were 7.22 feet long; the ends were closed by riveted pieces or by the bending of the top table of the tie, and the rail fastenings consisted of bolted clamps. The weight of fastenings for each tie was 3.3 pounds for the four clamps, and 3.3 pounds for the four bolts. The "Vautherin" ties weighed 77 pounds each, and the "Berg-and-Mark" ties 83.6 pounds each, exclusive of fastenings. The ties are placed in cuttings and on embankments, on different kinds of ground and on grades as steep as 1.5 per cent. On 47.74 miles of the line between Kutchuk-Tchekmedje and Kouleli-Bourgas, they have been laid on curves of 1,968 feet radius and on tangents connecting two curves; on the remaining 22.94 miles they were laid on tangents and on curves of different radius. These lines have a light traffic, averaging for both directions one to four mixed or loaded freight trains per day. The suburban line from Constantinople to Kutchuck-Tchekmedje is an exception, having nearly thirty trains per day in both directions. The maximum speed allowed is 26 miles per hour. The locomotives have three axles and weigh 36 tons. The track is laid with steel rails weighing 41.16 miles per yard, having the ties spaced 32 inches, center to center, and iron rails weighing 68.5 pounds per yard, having the ties spaced 3.28 feet, center to center. The ballast is of different materials, from fine sand to broken stone; the use of metal ties has shown the necessity of replacing the fine ballast, or at least mixing it with a coarse ballast.

The experiments date from 1879, when the first 600 ties were laid; since then ties have been laid as follows:

Type.	Year.	Ties.
		No.
Vautherin	1880	13,300
Do	1881	7,800
Do	1882	6,700
Berg-and-Mark	1883	13,400
Do	1884	31,400
Do	1885	31,000
Do	1886	16,500
Do	1887	9,390

With fine ballast, the maintenance expenses are higher than those with wooden ties; but with coarse ballast the maintenance expenses of tracks on metal and wooden ties are about equal (allowance being made for the expense of renewing wooden ties). The trials with fine ballast have also been unsatisfactory, because with a spacing of 3.28 feet between the ties the resistance to lateral motion is too little unless good ballast is used, preferably broken stone. No wear of the body of the tie had been observed, so that no limit of the life of the tie could be determined. With a good seat for the rails the tracks with wooden or metal ties present the same advantages as to the preservation of the rolling-stock, the elasticity of the track and the comfort of the passengers.

The company reported that the intention was to continue the use of the "Berg-and-Mark" type of ties, if the price could be made suitable. They were not able to establish a relation between the prices of wooden and metal ties to enable them to decide that the use of the latter was more advantageous. They were of the opinion, however, that the use of metal ties was not an advantage when the net cost was double the cost of wooden ties; but, on the other hand, they considered it to be an advantage to use metal ties when the price was only one and a half times that of wooden ties. For the comparative calculations respecting the two forms of track, they took pine or beech ties, treated with chloride of zinc, and each provided with two tie-plates; they only counted the value of one of these plates, however, because they last much longer than the wooden ties.

SUMMARY OF METAL TRACK FOR SECTION NO. 1.

Countries.	Bowls.	Longitudinals.	Cross-ties.	Total.
	Miles.	*Miles.*	*Miles.*	*Miles.*
England			70.00	70.00
France			52.12	52.12
Holland		8.06	321.36	329.42
Belgium			115.50	115.50
Germany		5,224.12	3,562.52	8,786.64
Austria and Hungary		66.56	56.56	122.93
Switzerland		.25	303.93	397.40
Spain	251.68		7.10	258.78
Portugal			.02	.02
Italy				
Sweden and Norway			.50	.50
Denmark			18.10	18.10
Russia				
Turkey			70.68	70.68
Total	251.68	5,298.99	4,578.25	10,222.09

SECTION 2.—AFRICA.

EGYPT.

GENERAL REMARKS.—In this part of Africa metal track has been in service since 1854. The type of track generally used consists of ties made of a pair of cast-iron bowls connected by a transverse tie-rod. This form of tie was originally used for a railway line in Egypt; the greater part of its length was through the desert, and it answered very well, as the fine loose sand made a ballast especially adapted for this type of tie. Now, however, this track is unfavorably considered by the consulting engineer of the railway administration, as noted in the following paragraph. It has been generally understood, however, that wooden ties were not suitable for the climatic and other conditions existing in Egypt, being destroyed rapidly by the heat, by insects, and by other influences.

EGYPTIAN RAILWAYS.—Through the courtesy of Mr. George H. Wright, of London, engineer for the railway administration, I am enabled to give the following details of the track, from a statement prepared from notes taken in 1887. Mr. Wright, in a communication received in August, 1889, stated that wooden ties only are now imported into Egypt; in his opinion they are much to be preferred to the iron bowl ties, as they make a better road and cost less to maintain. He stated, however, that the steel plate ties (presumably of the type used on the Indian state railways) would probably prove better than either the wooden or bowl ties.

Track of Egyptian Railways.

Lines.	Opened.	Miles.	Track.		Notes of 1887.
			Rails.	Ties.	
District No 1.					
Cairo to Tanta	1856	53½	D. H.	Bowls	37¾ miles iron rails, old bowls, 15¾ miles, steel rails, new bowls, laid in 1887.
Tanta to Kafr-Zayat............	1855	12½	D. H.	....do......	Steel rails on new bowls, laid in 1885.
Cairo to Callioub	1861	8¾	D. H.	....do......	Rails iron, worn, ties fair condition.
Callioub to Benha...............	1866	19½	D. H.	....do.	Do.
Benha to Tanta	1865	25¼	D. H.	....do	Do.
Tanta to Kafr-Zayat........ ..	1859	12½	D. H.	....do..	Steel rails and bowls, laid in 1886.
Benha to Mitbeneh	1861	3½	D. H.	.. do......	Iron rails, and ties in good order.
Barrage Branch..................	1865	6¼	D. H.	....do	Do.
Cairo to Heloan Junction......	1876	7¾	D, H.	...do......	Iron rails some wooden ties.
Heloan Line	1876	5	D. H.	....do	Do.
		7	D. H.	Vantherin	Some ties in bad condition.
		3	F.	Wood.....	

Track of Egyptian Railways—Continued.

Lines.	Opened.	Miles.	Track.		Notes of 1887.
			Rails.	Ties.	
District No. 2.					
Kafr-Zayat to Millaha	1854	57	D. H.	Bowls	22 miles, steel rails, old bowls, laid in 1880-'81.
Kafr-Zayat to Millaha, second track	1855	57	D. H.	do	92 miles, steel rails, new bowls, laid in 1882-'85.
Millaha to Sidi-Gabir	1876	1½ 1¼	D. H. D. H.	Wood Bowls	Old wooden ties in good condition. New steel rails and bowls, laid in 1887.
Sidi-Gabir to Alexandria	1876	3¼	D. H.	do	Do.
Sidi-Gabir to Alexandria, second track.	1876	3¼	D. H.	do	New steel rails and bowls, laid in 1885.
Millaha to Gabbay	1854	6¾	D. H.	do	A few wooden ties.
Millaha to Gabbay, second track	1855	6¾	D. H.	do	
Gabbay to Mex	1862 1875	3½	D. H.	do	A few wooden ties.
Rosetta Line	1876	39½ 1	F. D. H.	Wood	Extensive renewals required.
District No. 3.					
Tanta to Cheibin-el-Com	1866	17½	D. H.	Bowl	In good condition.
Tanta to Mehallet-Roh	1857	8½	D. H.	do	New bowls laid to replace wood, to do away with a mixed track.
Tanta to Mehallet, second track	1877	8½	D. H.	do	1 mile of new rail and bowls laid in 1886.
Mehallet-Roh to Samanoud	1859	7½ 2 1 2½	D. H. D. H. D. H. D. H.	Wood Bowls Wood do	 Bowls laid to replace wood, to do away with mixed track. Being relaid with iron bowls. 17½ miles of ties, much corroded.
Samanoud to Damietta	1869	38¾ 2¾ 9¼	D. H. F. F.	Bowls Wood Vantherin	Pine, replacing old iron trough ties. Ties in bad condition.
Zifteh Branch	1865	18¾	D. H.	Bowls	
Dessoub Branch	1865	32½	D. H.	do	Ties in good condition.
Kafr-Sheik Branch	1875	11	F.	Wood	
District No. 4.					
Benha to Zagazig	1860	21½	D. H.	Bowls	Tie-bars too long.
Benha to Zagazig, second track	1870		D. H.	do	
Zagazig to Suez and docks	1868	60¼ 39 4¼	D. H. D. H. D. H.	do Wood Steel	Buckled steel.
Callioub to Zagazig	1865	38	D. H.	Bowls	
Zagazig to Mansourah	1865	44	D. H.	do	
Salhiel Branch	1869	2 19	D. H. D. H.	Wood Vantherin	5 miles must be renewed before 1889.
District No. 5.					
Tchad-el-Baroud to Boulak-Dakrour.	1872	43 26 5	D. H. D. H. F	Bowls Wood do	
Boulak-Dakrour to Wasta	1867	51	D. H.	Bowls	5¾ miles of new bowls, laid in 1884, 1886.
Wasta to Fayoum	1868	23¼	D. H.	do	
Fayoum to Abouxa	1869	14¾	D. H.	do	
District No. 6.					
Wasta to Minieh	1867	97	D. H.	Bowls	
Minieh to Millani	1870	29½	D. H.	do	
Millani to Assiout	1874	2½ 49	D. H. F.	do Wood	

SUMMARY OF MILEAGE.

District.	Iron bowls.	Vantherin cross-ties.	Steel plates.	Wood.	Total metal.	Total.
No. 1	157½	7		3	164½	167½
No. 2	138¾			42	138¾	180¾
No. 3	126½	9¼		24¾	135¾	160½
No. 4	163¾	19	4¼	11	187	228
No. 5	132			31	132	163
No. 6	129			49	129	178
Total	817½	35¼	4¼	190¾	887	1,077¾

The total length of lines, including sidings, in 1887, was 1,228¼ miles.

EGYPTIAN AGRICULTURAL RAILWAYS.—A type of metal track used on these lines consisted of ties made of a pair of wrought-iron plates connected by tie-bars. (See plate No. 17.) The plates were rectangular in shape, 18 inches long, about 15½ inches wide, and seven thirty-seconds of an inch thick. When bent to shape each plate is flat for its whole length and for a width of about 5½ inches; the sides are bent down, flaring out to a width of 13 inches over all at the bottom, and the corners are bent in to a width of 10¾ inches over all. The depth is then about 2¾ inches. Each pair of plates is connected by a transverse tie-bar, 6 feet 2 inches long, 1⅞ inches deep, and three-eighths inch thick, placed on edge; it is secured by a key or cotter on the inner and outer side of each plate. The keys are 6 inches long, 1¼ inches wide at the ends, 1½ inches wide at the middle, and three-eighths inch thick; the edge bearing against the plate is beveled to the same slope as the side of the plate. The holes in the tie bar are 1¾ inches long by three-eighths inch deep. The hole in the outer side of each plate is slightly lower than the hole in the inner side, so that the top of the plate is inclined and gives the rail the usual inward inclination. The track is 4 feet 8½ inches gauge. The joint-ties are spaced 2 feet 4 inches apart, center to center of tie-bars, and the intermediate ties are spaced 3 feet 1¼ inches apart. The rails are of flange section, weighing 42 pounds per yard; they are $3\frac{17}{32}$ inches high, with a flange 3¼ inches wide and a head 2 inches wide. The joints are suspended, and are spliced by a pair of straight, flat splice-bars 15 inches long, weighing 9.60 pounds per pair; there are four bolts three-fourths inch diameter, and the weight of the nuts and bolts is 3.24 pounds per set. The rail-fastenings consist of three clips; on the outer side there are two clips 3 inches long, each fastened by a rivet eleven-sixteenths inch diameter; on the inner side is a similar clip, secured by a bolt three-fourths inch diameter, with a ⊥ head on the under side of the plate. The weight of each tie complete is 60 pounds. The average weight of the track per yard is 140 pounds.

The following is the weight of material per mile of single track:

	Tons.	Lbs.
Rails	66	.....
Ties	47	320
Splice plates and bolts with rails:		
24 feet long	2	1,170
21 feet long	2	1,976
18 feet long	3	812

SUAKIN RAILWAY.—During the English campaign in Egypt in 1885, a short section of light railway was laid near Suakin for military purposes. According to information received from the war office, the track was of the type manufactured by John Fowler & Co., of Leeds, England, for portable and light railways. The line had a gauge of 18 inches. The ties were of steel, 3 feet 9 inches long, of shallow inverted channel section, with a deep groove or corrugation lengthwise of the middle of the tie. At each end of the tie were two brackets, each secured by two rivets; the outer pieces were angle irons, with the upright web inclined toward the rails; the inner pieces were made to fit the web and flange of the rail. The ties weighed 35 pounds each, complete. The rails were of flange section, weighing 24 pounds per yard, and were secured by oak keys or wedges driven between the web of the rail and the outer angle bracket. A number of these ties were laid, but the line was taken up at the end of the campaign, and the time during which they were in service was too short for any opinion to be formed as to their durability.

ALGERIA.

Algerian Railways (*Paris, Lyons and Mediterranean Railway*).—The Paris, Lyons and Mediterranean Railway, of France, which has not had success with metal ties on its home lines (see "France") has used them with very satisfactory results on the Algerian lines which it owns. These lines are from Oran to Algiers, 264.12 miles; and from Phillipville to Constantine, 53.94 miles. The conditions, however, are by no means the same; the burning climate of Africa causes the very rapid destruction of wooden ties, while the metal ties stand very well under the comparatively light traffic, and effect a decided economy over wooden ties by their greater durability.

During 1867, 1868, and 1869 between 90,000 and 100,000 (reported as 93,762) iron ties of the original "Vautherin" type, with short flanges on the lower edges, were rolled at the Fraisant Works in France, and were laid on the Algiers and Oran line. They were 7.87 feet long, 5.2 inches and 3.2 inches wide on top for joint and intermediate ties respectively; about 7.2 inches wide inside at the bottom, and 10.4 inches wide over the flanges, which were 1.4 inches wide and .32 inch thick; the sides and top table were .18 inch and .28 inch thick respectively. The ends of the tie were open. The weight was about 77 pounds. The rails rested on tie plates which gave them the required inward inclination of 1 in 20, and were secured by a gib and cotter fastening; there was a gib holding each side of the rail flange with a cotter driven vertically at the back of the inner gib; the fastenings passed through the tie plate and tie. The number of renewals in seventeen years was 3,200, caused principally by cracks due to bad metal or improper tamping. The cracks were generally in the angles, and went from the ends toward the rail seats. There was no trouble from rust, and the experience of these seventeen years was favorable to the metal track. The metal was of inferior quality, and the attachments of the rails were defective. In 1885 there were still 91,000 of these ties in service. The average age of the ties in 1885 was 17 years, and the total of renewals during that period was 3½ per cent., while the renewals of wooden ties are about 10 to 12 per cent. per annum. Owing to this difference the iron ties had repaid the extra cost of establishment incurred by their use (principal and interest) in the fifth year, and the remainder of their service was a net gain in maintenance. From their state of preservation in 1885 it was estimated that they would give twenty-five years of service. From this trial it was concluded that metal ties behaved well in the ballast, that they do not rust or fail, and that the few renewals are due to defects in the ties or track, and not to a short average life of the ties. They cost less for maintenance, but up to the third year it is necessary to tamp the ballast and inspect the fastenings frequently; after that the attention is not required.

In 1885, 20,000 steel ties of the "Hilf" or original "Berg-and-Mark" type were laid. (See plate No. 17). They were manufactured in France by the Société de Denain et d'Anzin. These ties are 7.5 feet long, of uniform section throughout; 4.4 inches wide on top, 8.4 inches wide on the bottom, 2.4 inches deep, with the sides vertical for 1 inch from the bottom; the sides are .28 inch thick; the top table is .32 inch thick, with a rib on the underside 1.44 inches wide, making the thickness .52 inch. The weight is 85 pounds, or 96.8 pounds including the fastenings. The tie is horizontal for 3 feet 3⅜ inches at the middle, and is inclined upwards at an angle of 1 in 20 to the ends, which are closed by bending down the top table to a depth of 4 inches. The rails are of flange section and rest directly on the tie. Gib and cotter fastenings are used, but a third gib ("guard-gib") is now used, to increase the bearing area at the back of the cotter. The holes at each rail seat are 1.36 inches and 2.48 inches long, spaced 3.48 inches apart in the clear. In May, 1887, 35,000 ties of the "Vautherin" type were ordered, and in February, 1888, 60,000 steel ties were being laid.

Mr. Mazieres, the engineer, made a report to Mr. Bricka in 1884, stating that in spite of defects in the earlier ties the general results of the track had been satisfactory. On the Algiers and Oran line not a single derailment had occurred.

The following information was presented at the International Railway Congress at Milan, Italy, in 1887, by Mr. Kowalski:

> There were 68.82 miles of metal track in service, including 91,000 iron ties of the Vautherin type and 20,000 steel ties of the Hilf type. The fastenings were of iron, weighing 5.28 pounds per tie for the former and 5.46 pounds per tie for the latter, making a total weight per tie of 82.28 pounds and 100.98 pounds respectively. The line was principally on low embankments; there were curves of 1,640 feet radius and upwards, long tangents, and grades of 2 per cent. The traffic consisted of passenger and freight trains running at various speeds; 54,000 trains had passed over the Vautherin ties; the speeds varied from 18.60 to 34 miles per hour. The engines weighed from 30 to 35 tons. The rails were of flange section, of iron, weighing 72.4 pounds per yard for the Vautherin ties, and of steel, weighing 68.8 pounds per yard for the Hilf ties. The ballast was of river sand mixed with sand and clay of poor quality. The steel tie cost about 60 cents more than the wooden tie, but effected an economy of 20 cents in the ballast, a smaller amount being required. When the track is well settled the work of maintenance is about a fourth less than with wooden ties. The life of the steel tie was estimated at treble that of wooden ties, but this could not be considered as determined. The life of fastenings was about the same for metal as for wooden ties. As to the elasticity of the track, the comfort of passengers, and the effect on the rolling stock, these were the same as with wooden ties. The results had been satisfactory and it was intended to extend the use of the Hilf steel ties.

Bône and Guelma Railway.—In 1885 this road had had in service for more than two years 3,500 cross ties of the Severac type (see Belgium), and 2,500 ties of the Boyenval-Ponsard type (see France).

ABYSSINIA.

Massana and Sahati Railway.—In May, 1889, the state inspector general of railways of the Italian Government furnished a detailed statement in regard to this line, which was built by that Government for military purposes, but which has been in operation for too short a time to enable any conclusions to be drawn as to the durability of the track. The line is 14.26 miles long, of 3.12 feet gauge, with a maximum grade of 2.3 per cent. and sharpest curves of 328 feet radius. It is a military line, with a traffic of water, supplies, and troops. The track was laid in March, 1888, under the supervision of Mr. Vernan. The engines weigh from 20 to 30 tons. They have four driving wheels, with a weight of about 5 tons in each wheel. The ties are of steel, of the Vautherin type, but without flanges on the lower edges, the sides being nearly vertical for .40 inch from the bottom. They are 4.92 feet long, 3.6 inches wide on top, 7.2 inches wide at the bottom, and 2.4 inches deep. The sides and top are about .25 inch thick, but a rib on the under side of the top table increases the thickness to .32 inch for a width of 1.44 inches. The ends are closed by bending down the top table. The tie is horizontal, but at the rail seats the top table is inclined 1 in 20, to give the rails the usual inward inclination. It is bent on the Hosch-Lichthammer plan (see Holland), the outer part of the rail seat sloping back to the normal level of the tie. The ties weigh 39.6 pounds each. They are not painted or otherwise treated for protection against rust, etc. They were manufactured by Tardy & Benech, of Savona, and the prices were $35 per ton for ties, $56 per ton for clamps, $76 per ton for bolts and nuts, all delivered at Naples. In the track the ties are spaced 32.8 inches apart, center to center. The rail attachments are of the Ruppel type (see Germany), consisting of ⊥-headed bolts .64 inch diameter, with clamps 2 inches wide, one side of which holds the rail flange and the other bears on the tie, having a lug which fits into the bolt-hole in the tie. Adjustment of gauge is effected by the use of clamps with different widths of projection of the lugs. Two sizes of clamps are used at each rail, and the gauge on tangents and easy curves is 3.12 feet. By transposing the two clamps of one rail the gauge is widened .24 inch for curves of 984 to 656 feet radius, and by transposing the two clamps of both rails the gauge is widened .48 inch for curves of 656 to 460 feet radius. At each rail seat are two holes 1.6 inches long by .72 inch wide, spaced 3.28 inches apart in the clear. The rails are of flange section, 4 inches high, with a flange 3.2 inches wide and a head 2 inches wide. The weight is 46.26 pounds per yard. The joints are suspended and are spliced by plain bars. The ballast is of broken stone or gravel 14 inches deep, with the top level with the under side of the rail heads. The passage of the first trains packs the ballast well into the ties. The width at subgrade, for single track, is 11.48 feet. These ties were adopted on account of the short life of wooden ties in the tropical climate. The general results have been satisfactory. The system is very simple, the track is easily laid, and maintenance, renewals, alignment, etc., are easily effected. For surfacing, whenever depressions occur the track can readily be elevated by tamping gravel under the ties. The gauge also is always accurately maintained, while with the wooden ties spreading of the rails occurs on curves of short radius. Wooden ties would have cost 60 cents each at Naples.

SOUTH AFRICA.

(*Portuguese territory.*)

Delagoa Bay and East African Railway.—This line runs inland from the port of Lourenco Marques, or Delagoa Bay, to the boundary between the Portuguese territory and the Transvaal, a distance of 50.22 miles. A report from Mr. Thomas Rumball, of London, the consulting engineer, in April, 1889, stated that 42.16 miles were then laid with steel cross-ties and the remainder with wooden ties; the reason for this was that the manufacturers could not keep up the supply of steel ties, and as the contract required the completion of the road within a certain time wood had to be used. An extension of 5.58 miles, however, was then being laid with steel ties. The track was laid between April and November, 1887, under the superintendence of Mr. A. B. Rumball. The steepest grade is 1 in 40, and the sharpest curve is 1,320 feet radius. There are comparatively few curves, 45.26 miles of the line being straight and only 4.96 miles on curves. The gauge is 3 feet 6 inches. The locomotives are six-wheel "bogi" tank-engines (*i. e.*, with trucks), weighing 33 tons in full working order, and having a weight of 10 tons on the driving wheels, The freight consists of gold-crushing and other machinery, colonial produce, hides, etc.

The ties are of similar type to those adopted for the Indian state railways. They are 6 feet long over all, horizontal in the middle, bent up at the rail seats to give the rails an inward inclination, and have the ends curved down and flared out to a width of 13 inches (see Plate No. 17). At the middle the sides are vertical and the top is arched; at this point the tie is 8¼ inches wide at the bottom and 5 inches deep; the sides are eleven-sixty-fourths inch thick, and the top is slightly thicker for a width of 4½ inches, the extra thickness being added on the upper side. At the rail seat it is flat for a width of 4½ inches on top, 9½ inches wide at the bottom, and 4½ inches deep; the sides are slightly curved and flare outward; the sides are one-fourth inch thick and the top is seven-sixteenths inch thick, the extra thickness being added on the upper side for a width of 4½ inches and on the lower side for a width of 4 inches. There is a clip 3 inches long stamped out of the top table of the tie for each side of each rail, and the taper steel split keys are driven between the outer clips and the rail flanges. The ties are of steel, weighing 70 pounds each, and the keys weigh 1¼ pounds per pair. The joint ties are spaced 2 feet apart, center to center, and the intermediate ties are spaced 3 feet 3 inches apart. They were manufactured by the Moss Bay Hematite Company, of Workington, Cumberland, England, and cost 90 cents each at the works. The ties are dipped in a boiling solution of Dr. Angus Smith's composition, and the keys are dipped in boiling linseed oil. An improvement in these ties has been patented by Mr. H. Law.

The rails are of flange section, weighing 56 pounds per yard; they are 4 inches high, and 4 inches wide over the flange; the joints are suspended and are spliced in the usual way. The road is ballasted with sand and broken stone; the ties are considered to be better adapted for sand, as the ballast packs well into the tie. The durability of the ties had hardly been tested, as the road had only been open for about two years at the time of Mr. Rumball's communication, but it is confidently expected that they will not require renewal for thirty years. The cost of maintenance can only be arrived at so very approximately as to be of no value, since the line has been subject to severe floods. The labor for track-laying was entirely unskilled, but it was found in practice that the Kaffirs very quickly got into the way of "threading" the ties on the rails. The steel ties were adopted on account of timber-ties being eaten away by the white ants in a short time. They are very satisfactory, and the running over them is very smooth. The engineer thinks that in a country like Africa steel ties should be used in preference to wood.

CAPE COLONY.

CAPE GOVERNMENT RAILWAYS.—These lines aggregate 1,523.75 miles in length. They are of 3 feet 6 inches gauge, and have maximum grades of 1 in 40 and minimum curves of 400 feet radius. The following particulars in regard to the track are abstracted from a paper by Mr. Wm. Geo. Brounger, presented to the Institution of Civil Engineers (London) in 1885. (Proceedings; Vol. LXXXI; session 1884–'85; Part III.)

Steel rails of flange section are used weighing 45 and 60 pounds per yard, with suspended spliced joints, and spiked or bolted to creosoted Baltic ties, 7 feet by 9 inches by 4½ inches for the lighter rails, and 7 feet by 10 inches by 5 inches for the heavier rails. With a view to check the tendency to spread of gauge round the sharp curves of the Hex River Mountain, on the Western division, bowl ties of Livesey's pattern were ordered for a few miles for the sake of the wrought-iron tie-bar, all the different kinds of fastenings employed being found to yield in the case of wooden ties, even where hard wood was used, though the latter checks the tendency to some extent. This piece of track has answered well under a trying traffic. Most of the ties were of cast-iron, but a length of 1 mile was laid with wrought-iron. Of the latter not a single tie had to be replaced, but many of the former were broken during the process of packing. In consequence of the difficulty and uncertainty in obtaining wooden ties, the increase of their price, and the delay in procuring them, it was decided to try iron ties on a more considerable scale, and 36¾ miles of wrought-iron trough ties and 73½ miles of wrought-iron bowls, both of Livesey's patterns, had been laid down. They had only been recently laid, so that little could be said as to the results, but the following particulars were given:

First. Both types require careful packing. In the case of the bowls, if this is not done, they are apt to get out of level transversely, and the result is a cant, which throws the line out of gauge.

Second. Special care is essential in the manufacture of both kinds, particularly in the fixing of the jaws, otherwise the gauge is affected.

Where irregularity occurs in the spacing of the holes in the bars, adjustment of gauge on curves is given with bowls by placing the cotter on the inner side, instead of the outer side, of the bowls; on sharp curves this may be done with both bowls. With the iron trough ties it is desirable that special ones should be provided for sharp curves, with allowance for slack, such ties having unmistakably distinctive marks to prevent confusion, or otherwise some safe means of adjusting the jaws for gauge.

[The use of special ties for curves is not to be recommended, as it is probable that the right ones will not be at hand when wanted, and they complicate the track-laying. There are better means of adjusting the gauge by means of the fastenings.—E. E. R. T.]

Third. More care is requisite as regards ballast, and this has been a source of trouble. It is undesirable that the ballast should be coarse for these ties, but it is often difficult to obain it fine, it being sometimes necessary to use broken stone for top as well as bottom ballast.

Various kinds of timber have been tried in order to test their durability as ties. Some varieties from colonial forests have given favorable results, but their cost has been prohibitory. A species of timber from Madagascar proved durable, but its export was attended with difficulty. The timber which has hitherto proved the most durable is that of the camphor tree, which has been taken up after being in the ground for twenty years, without any preparation, and found perfectly sound through heart and sap wood. The Government, therefore, decided to make plantations of this tree, which, under favorable conditions, attains a large size in the Colony,

The following particulars are from a communication received in December, 1889, from Mr. H. C. Litchfield, and referred to the Junction or Hanover line, built in 1883–'84:

The Hanover line is, approximately, an east and west line, over an open, treeless and bushless, undulating country, 300 miles from the coast, and with an average elevation of 4,500 feet above sea-level, crossing at right angles the main streams flowing northwards to the Orange River. It is about 70 miles in length, with maximum grades of 1.25 per cent., and sharpest curves of 8° 40′. The ties were spaced 2 feet at the (all opposite) joints, the intermediate ones being spaced (to the nearest inch) 2 feet 9 inches for wooden ties, 2 feet 5 inches for iron trough ties, and 3 feet 2 inches for bowl ties. The wooden ties were all 7 feet long, and of two sections, the heavy being 10 by 5 inches and the light 9 by 4½ inches; they were all imported Baltic red fir creosoted with not less than 10 pounds per cubic foot of timber of the best creosote oil, weighing not more than 10 pounds per gallon. The weight of each heavy tie when dry was 110 pounds, or 80 tons per mile. The rails were fastened by spikes. The weight of the iron trough tie was 66¾ pounds, or 68.1 pounds with the keys. The weight of a pair of bowls was 74 pounds, and of the tie-bar 12 pounds; the weight complete, with the keys, gibs, and cotters, was 88.27 pounds per tie. The weights per mile of these two kinds were 62 and 62.21 tons, respectively. The prices in 1883–'84, landed at the nearest port, Port Elizabeth, were $1.32, $1.84, and $2.26 each, respectively, or $2,608 (including spikes), $3,833, and $3,625 per mile. Steel rails were then $35 per ton, free on board, and freight to South Africa about $6.25 per ton. The rails were mainly 24 feet long, and 23 feet 10 inches long for curves; none were longer than 24 feet. With regard to the bowl ties, on tangents the gibs were placed inside, and the cotters outside, of the track, giving a gauge of 3 feet 6 inches on flat curves one gib was placed outside, giving a gauge of 3 feet 6¼ inches, and on sharp curves both gibs were placed outside, to give a slack gauge of 3 feet 6½ inches. In order to insure the bowls being packed, a mound or hillock of ballast was first made for each to rest upon; when the ties were placed in position a rail was laid in and keyed up on one side of the track first, and the opposite rail put in and keyed up afterward. The large lug of the bowls was tapered to suit the corrugated key, and the key was driven by the right hand of a man standing between the rails, so that all keys on the left hand rails pointed backwards, and those on the right hand rails pointed forwards, with the mileage.

NATAL.

NATAL GOVERNMENT RAILWAYS.—These lines are also of 3 feet 6 inches gauge. Originally the track consisted of iron rails laid mainly on imported creosoted ties, the average life of which was about seven years. Since about 1884 native yellow-wood ties have been tried, but their life is only about two and one-half years, and soaking them in mineral oils was not found to be of much service. Good ballast is difficult to obtain, and poor grades of disintegrating shales, quartzites, and crystalline rocks are frequently used. Steel rails are being laid on some parts of the line, and on some of the extensions a track of steel rails on plate ties had been laid.

Mr. Kielland, an engineer who had some experience with the early railways of the Colony, informs me that with the exception of a small piece of line from Durban to the Umzemi River, about 4 miles, no railways had been constructed previous to 1876, when the location of the first Government railways was commenced. In 1878–'79 regular trains began to run. The ties used on these first roads were of creosoted pine, about 7 feet by 6 inches by 6 inches. It is reported that there is very little timber in Natal or the Cape Colony which is suitable either for ties or railway structures, the timber, as a rule, being hard and crooked. In the country north of Zululand, Mozambique, and Madagascar there are said to be immense tracts of swampy land, covered with a very lasting magnolia or mangrove tree, which is thought to be suitable for ties.

SOUTH AFRICAN REPUBLIC.

(*Transvaal.*)

The Dutch company owning the railways awarded a contract in October, 1889, for 71,430 steel ties of the Post type (see Holland).

CONGO FREE STATE.

CONGO RAILWAY.—This road is to be built by a Belgian company, and it is reported that Belgian works will supply steel rails and steel ties. The latter will probably be of the Post type.

SENEGAL.

About 5,000 cross-ties of the Severac type (see Belgium) have been used in this French colony.

ISLAND OF REUNION.

On the Island of Reunion, off the east coast of Africa, a French possession, there is a meter gauge railway 77.5 miles in length, built in mountainous country, at a cost of $48,000 per mile. The track consists of steel rails of flange section, weighing 28.2 pounds per yard; these were originally laid on preserved pine ties, imported from France, spaced 28 inches apart, center to center, but iron bowls arranged in pairs, on the Livesey system (see England), as employed with success in South America, have been substituted, and so far have given satisfactory results. The bowls are laid in broken stone ballast. The locomotives weigh 15 tons in working order, and can haul a load of 50 tons over the steepest grades. The traffic consists of about five trains per day, at an average speed of 15.5 to 18.5 miles per hour. For the sake of economy the location follows the surface of the ground as nearly as possible; this necessitates numerous curves; but these have caused no inconvenience in operation on account of the slow speed necessary to satisfy the demands of the traffic. There are curves of 351, 410, 492, and 656 feet radius. The steepest grades are 2 and 2.5 per cent. The conditions of the traffic led to the adoption of a light track. The imported pine ties only lasted two years, and trials with native wood from Madagascar, even with mangrove, not having been successful, metal ties were adopted.

Each tie (Livesey) consists of a pair of cast-iron bowls flattened on the upper part to form a seat for the flange of the rail, and having lugs between which the rail is held by a corrugated key. The gauge is maintained by means of a wrought-iron tie-bar connecting each pair of bowls and secured by keys. The spacing of the keys, and consequently the length of the tie-bar, can be varied at will, thus permitting an adjustment of the gauge at curves, etc. The ties are spaced about 3.28 feet apart, center to center of tie-bars. For over three years (up to 1888) 62 miles of track had been laid with this track and had not required any maintenance. The ballast is of broken stone. The cars run smoothly, without jarring, and passengers can not distinguish this part of the line from that on which wooden ties are still used.

The following particulars were presented by Mr. Kowalski, at the International Railway Congress, held at Milan, Italy, in 1887:

> The Livesey system of cast-iron bowl ties was then in use on 62 miles, including a tunnel. Each tie, complete, weighed 128.4 pounds; the tie-bars weighed 2.8 pounds, and each key .71 pound. The rails were of flange section, weighing 28.2 pounds per yard. The ballast was of sand and broken stone. The traffic consisted of six to eight trains per day. The ties were laid in 1881, and have given good results, but

the jaws on the bowls have to be made heavier than at first, as they broke frequently. The price in London was $1.40 each, or $2 each delivered at Reunion. Wooden ties cost $1. The cost of maintenance was very small. There was no bad effect on rolling stock, and no unpleasantness to passengers, but this might have been due to the low speed. The only renewals have been of a few bowls broken by derailments. The use of these ties is to be continued. It is considered that the advantages of metal ties in tropical countries are indisputable. Native and imported preserved wooden ties only last two and a half years, while the iron ties last indefinitely, and the maintenance is very much less than with wooden ties.

SUMMARY OF METAL TRACK FOR SECTION NO. 2.

	Bowls.	Cross-ties.	Plates.	Total.
Egypt	847.50	35.25	4.25	887.00
Algeria	....	120.00	....	120.00
Abyssinia	....	14.25	....	14.25
Portuguese territory (South Africa)	....	47.75	....	47.75
Cape Colony	80.00	36.50	....	116.50
South African Republic	....	40.50	....	40.50
Senegal	....	2.50	....	2.50
Island of Reunion	62.00	....	....	62.00
Total	989.50	296.75	4.25	1,290.50

SECTION 3.—AUSTRALASIA.

AUSTRALIA.

GENERAL REMARKS.—The railways of each of the five colonies of Australia (South Australia, Queensland, New South Wales, Victoria, and West Australia), are for the most part owned and operated by the separate governments of these colonies, and are under the control of railway commissioners. A very complete account of these railways will be found in Engineering News, New York, March 30, 1889. It is of interest to note that metal ties have been introduced into this new country, of which comparatively little is known here, and that their use is likely to be extended. In one case (South Australia) they have been introduced on account of the destructiveness of white ants, and in another case (Queensland) they have been adopted, after a partial trial, for an up-country line for motives of economy. One feature of this latter case is that the system adopted is claimed to be specially adapted for light and economical construction and to be suitable for some of the western sections of the United States. Hard-wood ties are in general to be obtained in abundance, but they are liable to be attacked and rapidly destroyed by white ants.

SOUTH AUSTRALIA.

SOUTH AUSTRALIAN GOVERNMENT RAILWAYS.—In July, 1888, there were 1,500 miles of railway in operation, and two lines, aggregating 324 miles, under construction. The railways are of 5 feet 3 inches and 3 feet 6 inches gauge. The colony extends from the north to the south coast, and a north and south transcontinental line is to be built, some small sections of which are already in progress

On the Palmerston and Pine Creek line (3 feet 6 inches gauge) steel cross-ties are being used; full details have been furnished by Mr. A. B. Moncrieff, engineer in chief of the Government railways, and are given further on.

As this railway was not completed at the time of Mr. Moncrieff's report to me, and therefore sufficient information was not obtainable to answer some of the questions asked, he kindly sent the following particulars from a report of Mr. J. C. B. Moncrieff, M. Inst. C. E., the resident engineer of the Adelaide and Terowie line (5 feet 3 inches gauge), who had been directed to lay twenty-seven ties of the same design, but of the requisite size for the wider gauge, at the entrance to the Adelaide station yard, where they would sustain the heaviest traffic. The expense of maintenance was not greater than with wooden ties, but they had not been tested long enough to enable a decided opinion to be formed as to their durability. Gravel ballast was used, and it packed well, giving no trouble. The packing did not, however, fully drive up the ballast into the hollow of the tie, so that the chief weight had been carried by the flanges.

[This was one of the troubles with the original form of the Vautherin tie, and led to the substitution of a thickened rib instead of the horizontal flange on each of the lower edges.—E. E. R. T.]

There was no trouble with maintenance, but as the length of the track in use with these ties was only 40 feet, it was impossible to say whether they would keep the line straight. The rail attachments had given no trouble. Mr. J. C. B. Moncrieff thought very highly of these ties and considered that if they were a little stronger, especially around the rail seats, they would be a really serviceable article. From the results of these experiments he reported as follows:

> These ties are of the same thickness as those for the Palmerston and Pine Creek Railway (3 feet 6 inches gauge) and are, therefore, too slight for the heavier track with 61-pound rails, of these lines of 5 feet 3 inches gauge. They were twenty-seven in number, and were placed on the up and down tracks at the entrance to the Adelaide station. They were laid on April 19, 1886, and have been in use until now, June 3, 1889, except during a few days when they were taken out for inspection. Three have been removed on account of cracks in the rail seats, and round the holes for the attachments. There are now twenty-four in the track and these are in fairly good order, although some of them are showing cracks similar to those in the rejected ones. Apparently these cracks were originally started in the creasing of the steep angles round the rail seats. They have been in use for one hundred and fifty-three weeks, and have had a traffic of 6,500,000 tons over them during that time.

Wooden ties, of jarrah, red gum, or sugar gum, cost about 84 cents each, and last about twenty years, under favorable conditions, in the southern part of the colony, but their durability in the northern or tropical part remains to be seen.

Palmerston and Pine Creek Railway.—In June, 1889, I received a very complete and interesting statement from Mr. A. B. Moncrieff in regard to a government line of 3 feet 6 inches gauge being built from Palmerston to Pine Creek, in the northern territory of South Australia, a distance of 146 miles. The works are in general moderately light; there are 3½ miles of curves of 660 feet to 1,320 feet radius, the rest being of larger radius; the grades include 12 miles of 1 in 60 (1.66 per cent.) 15 miles of 1 in 60 to 1 in 80 (1.66 to 1.25 per cent.), and 12 miles of 1 in 80 to 1 in 100 (1.25 to 1 per cent.). The bridges are up to 100 feet span. The road was not then completed. The object of the road is to develop a mineral country, and the traffic is generally light. The locomotives weigh 24¼ tons, and have a weight of 6¾ tons on each driving-wheel; the tenders weigh 17 tons. Track laying was commenced in July, 1887, under the superintendence of Mr. J. W. James.

Metal ties were adopted on account of the destructiveness of white ants. The ties are transverse, of steel, of the type known as MacLellan and Smith's patent embossed stamped steel ties. (See plate No. 18.) They are manufactured by Ibbotson Bros. & Co., of England, and cost $65 per ton, free on board, at an English port. They are coated with Dr. Angus Smith's composition. The general form is that of an inverted trough, with closed ends, and having a horizontal flange all round the lower edges. The trough part is formed with corrugations at the ends and near the rail seats; this part is narrow at the middle, the top table and bottom flanges being of equal width; at the rail seats it is wide and flat, with narrow flanges; and at the ends it is wide, and is corrugated where it slopes down to the horizontal flange. The tie is 6 feet 3 inches long, 12 inches wide in the body, 14 inches wide at the ends and about 2¾ inches deep. The top table is about 3 inches wide at the middle and 7 inches wide at the rail seats. The length of the trough is about 5 feet 7 inches on the bottom, leaving 4 inches of flat plate at each end; the top is slightly arched or curved. The tie has a uniform thickness of three-sixteenths inch, and weighs 56 pounds; the fastenings weigh 6½ pounds per set. It is horizontal at top and bottom, but at each rail seat there is a depression $3\frac{9}{32}$ inches wide and about one-fourth inch deep on the outer side, forming a groove for the rail flange and having an inward slope of 1 in 26. This depression is an objectionable feature, as it is almost certain to cause cracks to start in the sharp angles, and this has been found to be the case. Experience in other countries has shown that proper fastenings are in themselves amply sufficient to hold the rails in place and prevent spreading of the track, so that this form of rail seat is therefore unnecessary. The expense and extra labor expended on this part may be dispensed with and a better and more durable tie obtained which will be fully as efficient in service as the tie with the depressed rail seat. The fastenings consist of two clips and one patent Ibbotson "twin" or U bolt for each rail. The horizontal part of the bolt rests inside the tie, under the rail seat, and the two vertical parts pass up through the top table and clips; these vertical parts are threaded and a nut is screwed down on each clip. The bolts are $4\frac{13}{16}$ inches long, center to center of the vertical parts, which are three-fourths inch diameter; the horizontal part is three-fourths inch wide and five-eighths inch deep, with the upper face flat, to bear against the under side of the top table. The clips are 2¼ inches long on the rail, 2¾ inches wide, and five-eighths inch thick at the middle. A groove is made in the outer clip and on the top of the outer side of the bolt, so that the track inspectors, when walking along the track, can see that the bolts and clips have been put in correctly. The ties are spaced as follows: For a rail length of 21 feet 2 inches, the joint ties are 1 foot 11 inches apart, center to center, the ties next to the joints 2 feet 4 inches, and the intermediate ties 2 feet 11 inches apart. For a rail length of 18 feet 5 inches, the joint ties are spaced 1 foot 11 inches apart, the next ones 2 feet 5 inches, and the intermediate ties 2 feet 11 inches apart. On curves they are laid radially.

At switches and frogs, wooden ties are used; they are 8 inches by 4 inches section, and 6 feet 6 inches to 13 feet long. The rails are fastened by steel spikes one-half inch square, 4¼ inches long, with heads 1 inch long by 1⅛ inches wide.

The rails are of steel, of flange section, weighing 41 pounds per yard. They are 3½ inches high, 3¼ inches wide over the flange; the head is 1⅞ inches wide, with a top radius of 6 inches and three-eighths inch radius of top corners. They are mostly 21 feet 2 inches long (20 feet 10¼ inches for short rails on curves), and some of them (not more than 5 per cent. of the contract lots) are 18 feet 5 inches long. The joints are suspended and are fastened by splice plates 15 inches long, with four bolts three-fourths inch diameter, spaced 3¾ inches center to center. The outer plate is flat, five-eighths inch thick, with bolt holes seven-eighths inch square, The inner plate is of a deep pattern, having a vertical web projecting below the flange of the rail, being 4¼ inches deep over all, and having the ends of the lower web cut to fit the slope of the sides of the ties; it is five-eighths inch thick in the upper web, and three-eighths inch thick in the flange and lower web; the bolt holes are seven-eighths inch diameter. The bolt holes in the web of the rails are oval, seven-eighths inch vertical by 1$\frac{1}{16}$ inches horizontal. A space of three-sixteenths inch is left between the rail ends at the joints. The ballast is of broken stone or clean gravel; it is 6 inches deep under the ties, 7 feet 6 inches wide on top, 10 feet 6 inches wide over the bottom; between the rails it is level with the tops of the ties, but outside it is nearly even with the level of the rail head, rounded down alongside the rail to the underside of the head. The minimum quantity of ballast, for single track, is 1,480 cubic yards per mile. The height from subgrade to top of rail is 12 inches.

There has not yet been sufficient experience to enable positive opinions to be given as to the value of these steel ties, but it is thought that they are rather too light, as they are found to crack slightly at the rail-seats and bolt-holes. The following particulars respecting the line are extracted from a report of the resident engineer, Mr. James:

> The steel ties are exceedingly strong, they stand well in the track and keep a good line. When traveling on an engine the road seems as elastic as if the line were laid with wooden ties. The contractors are highly pleased with them. They give no trouble when laid, and the cost for maintenance is very much lighter than with wooden ties.

The climate is tropical but it can not be said yet whether it will have any effect upon the ties.

QUEENSLAND.

QUEENSLAND GOVERNMENT RAILWAYS.—The lines in this colony are divided into ten divisions, and the condition of the railway system at the end of 1887 was as follows: Open for traffic, 1,895 miles; under construction, 208 miles; proposals invited for construction, 38 miles; plans approved, 197 miles; total, 2,338 miles. The gauge of the railway is 3 feet 6 inches. The average cost for construction has been about $32,070 per mile, and the average cost for maintenance for the years 1884–'85–'86 was $704 per mile per annum. The lines are laid principally with steel flange rails weighing 41¼ or 60 pounds per yard. There is said to be an abundant supply of iron-bark timber for ties. In September, 1886, a contract for 12,000 wooden ties for the Northern line was let at $8,250, or about 69 cents per tie. Sawn wooden ties cost from $65 to $90 per 100, and last from ten to fifteen years. The railway commissioner has condemned the further cutting of timber for ties, fences, etc., and has recommended the home manufacture of steel ties.

Some years ago (about 1882) 1,000 wrought-iron cross-ties of the Livesey pattern were laid on the Sandgate branch; they were 5 feet 6 inches long, made of metal three-sixteenths of an inch thick, and had closed ends. They lasted for five years under moderate traffic, but generally fractured under the rail seats, owing to defective fastenings of the rails. The oxidization was not serious. They were laid in ordinary broken stone ballast. In October, 1887, a contract for stamping 80,000 ties of the Phillips type was let to the Toowoomba Foundry Company, of Queensland, at $35,833.30. In December, 1887, a contract for 2,000 iron ties for the Southern and Western line was let at $4,156.25. In June, 1888, 100,000 ties of the Phillips improved type, weighing 84 pounds each, were being manufactured by the Toowoomba Foundry Company for the first section of the Normanton and Cloncurry Railway.

The ties designed by Mr. George Phillips, superintending engineer, late inspector of railway surveys, are intended especially for up-country lines; they dispense with ballast, the ground being plowed and the soil tamped into and around the ties. They are made of steel, and are of inverted trough section, with open ends (see Plate No. 19). These ties were first tried on the Harrisville branch of the Fassifern line, 80,000 being ordered. Of this first lot the plates were rolled in England and shipped flat, and were pressed cold to shape in the colony, as Mr. Phillips wished to inspect the work. They were imported by the Government at a cost of about $30 per ton, and the Toowoomba Foundry took the contract to do the shaping at 43 cents per tie. The work was to be done under very strict specifications, but after a time the contractors claimed that the plates were not delivered to them in a workable condition, and they applied for extra compensation.. It was said that owing to careless inspection in England the plates were sent out warped, twisted, and sometimes so unevenly cut that they would not go into the pressing machine. Two dippings in tar were specified, but the contract was modified to permit the contractors to make one dipping only, on condition that they would forego their claim for extra compensation. The first ties for the experimental line weighed 60 pounds; those now made weigh 84 pounds.

Mr. W. A. Cross, engineer of existing lines, in his report dated April 9, for the year 1887, stated as follows:

> An experimental line 65 chains 71 links long [4,336.86 feet if the English chain of 66 feet is used.—E. E. R. T.] was laid down in June last on the Harrisville branch, upon Mr. George Phillips's system, viz, a surface line having metal ties and without ballast, and has been tested by the whole of the traffic for the district having been worked over it for a period of ten months, with the result that a fair measure of success had been obtained for this description of light lines. The system merits consideration in opening up the vast plains of the interior of the colony.

In October, 1888, when the question of extending the Croydon branch railway from mile No. 13 to mile No. 42, from Normanton, a length of 29 miles, came before the legislature, there was quite a heated discussion as to the proposed use of metal ties. The contract for building a part of the line had been let by a previous administration to Mr. Phillips, who was to use his metal ties; as might be expected, the new administration disapproved of what had been done by the opposite party when in power, and this gave rise to considerable discussion. As shown further on, however, the line is being laid with these ties.

In May, 1889, the following particulars were furnished by the commissioner of railways in regard to the Phillips ties. They were laid on the Fassifern branch of the Southern and Western Railway, and on the first section of the Normanton and Croydon Railway. The length of track laid was 37 miles 1,980 feet, including sidings, and the laying of 60 miles more had been authorized. The maximum grade was 1 in 66 and minimum curve 660 feet radius. The ties were laid in 1887–'88 under the supervision of Mr. George Phillips and Mr. W. A. Cross, engineers. The traffic was mixed, passenger and freight, and the maximum of trains was six per day. The engines weighed 34$\frac{3}{5}$ tons, with 9 tons on the driving-wheels. The ties were transverse, of trough section, 5 feet 6 inches to 5 feet 9 inches long, 5 inches to 6 inches deep, and weighing from 60 to 84 pounds each. They were of wrought-iron and steel, and were manufactured by Springall & Frost and the Toowoomba Foundry Company in the Colony, from imported plates. They were dipped in a composition of coal tar and asphaltum, and cost $1.99½ to $2.50 each. The cost of maintenance was about $350 per mile per annum. They had not been done long enough to test their durability. The fastenings consisted of one riveted and one bolted clip to each rail. No special arrangement was made for curves. The lines are purely surface lines, with the exception of a few banks, the longest of which is only 1,980 feet in length; the ties are laid directly in the earth, no other ballast being used; the ballast behaves excellently under the tie. The rails are of flange section, 41¼ pounds per yard, with suspended spliced joints. The ties were adopted for economy in construction and maintenance, and so far the results had been perfectly satisfactory. There had been no trouble with the rail attachments, with maintenance, or from breakages.

FASSIFERN RAILWAY.—The following information relating to the first experimental line is condensed from a pamphlet issued by Mr. Phillips.

The Government having consented to lay down a short length of railway with wrought-iron ties (see plate No. 19), in order to test the practicability of working and maintaining railways laid on the surface of even country, without ballast or drainage of any description, the experimental line was laid in the form of a deviation near Harrisville, on the Fassifern branch of the Southern and Western Railway, upon a piece of even, black soil, melon-hole country, liable to be flooded after heavy rains to a considerable extent. The actual length of the experimental track was 4,336.86 feet, and on it were laid 1,988 wrought-iron ties. The ties were made for plates 66 inches long, 19 inches wide, and one-eighth inch thick; they were 5 feet 6 inches long, 6 inches wide on top, 9½ inches wide on the bottom, and 6 inches deep. At each rail seat a wrought-iron tie-plate, 12 inches by 8 inches by three-sixteenths inch thick, was fastened to the tie; on the outer side of the rail it was fastened by a three-fourths inch rivet which also held the clips for the outer side of the flange of the rail, and on the inner side by a three-fourths inch bolt which also held the loose clip for the inner side of the flange of the rail. The ends were open, and the ties were tamped from the ends. The rails were of steel, of flange section, weighing 41¼ pounds per yard. The total cost of the deviation, including the approaches (total length, 4,898.52 feet), was $10,350.25, of which $2,000 was due to the excessive price of the ties, which were manufactured (under contract) in the colony, at a cost of $2 each, or about $77.50 per ton, or about 100 per cent. of the value if they had been imported from England; steel ties were then, it was said, being manufactured in England for India at $22.76 per ton. The line was opened to traffic on June 11, 1887, and up to June 11, 1888, it had carried a gross traffic of 150,000 tons. It had been repeatedly submerged and in one instance trains were run over it at a speed of 25 miles an hour while the flood waters were running across the rails. The results were so satisfactory that the Government let a contract in June, 1888, to the Toowoomba Foundry Company for 100,000 ties of a heavier pattern for the Normanton and Cloncurry Railway. These ties were made from steel plates 5 feet 9 inches long by 18 inches wide and three-sixteenths inch thick; they were 5 feet 9 inches long, 7 inches wide on top, 10 inches wide at the bottom, and weighed 84 pounds each, complete. After the bending and riveting, they were dipped vertically, for about twenty minutes, into a caldron containing a composition of refined Trinidad asphaltum and coal-tar at a temperature of about 300° Fahr. It has been shown that this experimental surface line can stand the test of recurring heavy rain-falls without its stability being seriously affected.

CROYDON AND NORMANTON RAILWAY.—The ties for this line are made from steel plates 6 feet long, 18 inches wide before bending to shape, and three-sixteenths inch thick, with a strip 6 inches wide along the middle three-eighths inch thick; this extra metal may be on the upper or under side of the plate, at the option of the manufacturer (see plate No. 19). The tie is 6 feet long, 7 inches wide on top (or 6 inches if the extra thickness is on the upper side); 10 inches wide at the bottom, inside; 5 inches deep (or $5\frac{3}{16}$ inches if the extra thickness is on the upper side). The top corners are 1 inch radius, and the sides flare slightly outward. The top table of the tie is horizontal and the cross-section is uniform throughout. The rails are of flange section, of steel, weighing $41\frac{1}{4}$ pounds per yard; the flange is $3\frac{1}{4}$ inches wide. The outer flange of the rail is held by a riveted clip $4\frac{1}{2}$ inches long, $2\frac{7}{16}$ inches wide, three eighths inch thick, projecting seven-sixteenths inch over the flange. This clip is fixed at the exact place, with regard to the flange of the rail, to give the correct gauge, and it is secured by two five-eighths inch rivets, $2\frac{1}{4}$ inches apart. The inner flange of the rail is held by a loose clip, $2\frac{1}{2}$ inches square, seven-sixteenths to nine-sixteenths inch thick, projecting one half inch over the flange; the outer part has a rib on the under side which rests on the tie and so keeps the top of the clip horizontal. The bolt hole is thirteen sixteenths inch diameter. The bolt hole in the tie is kite-shaped, the point being turned toward the middle of the tie; it is $\frac{13}{16}$ by $1\frac{1}{16}$ inches. The bolt is $1\frac{3}{4}$ inches long under the head, three-fourths inch diameter, with the Whitworth thread, and has an eccentric neck 1 inch long, fitting into the narrow part of the bolt hole so as to prevent the turning of the bolt.

In January, 1889, Mr. Phillips sent the following report of his ties, and his statement, together with the other information given, shows that under certain circumstances, at least, steel ties are adapted not only to replace wooden ties on the main lines with heavy traffic, but also for an economical construction of railways with small traffic in even country:

> I have just returned from North Queensland, where I have been constructing a section of railway 36 miles in length on my system. The country I am dealing with is between the port of Normanton, in 17° 45′ south latitude and 141° 10′ east longitude, and a new gold field by the name of Croydon, situated about 85 miles east-southeast from Normanton. The country is almost uniformly even, and the Norman River is the only important river crossed. The first 4 miles are over gravel ridges, when a descent of 1 in 70 for half a mile brings the line down to the level of the river flats; the soil is dark clay with a slight admixture of alluvial sand. This description of country extends to 14 miles, where the river is crossed with a low, level timber bridge (principally 20-foot spans) on a sandstone-rock bottom. Thence to Croydon the country is very uniform in character—fine sandy soil, covered with a more or less thick forest of inferior and stunted timber, sometimes dense enough to be called

brush or scrub. There is no forest timber of sufficient dimensions in the district available for ties or bridge work, neither is there any stone for ballast, except by quarrying below the surface, and that is sandstone of an inferior and very soft description. The country is almost uniformly even, except at the 4-mile peg, where there is a cutting of about 5 feet and an embankment of equal height. I commenced track laying July 7, and completed 32 miles on December 29; fully seven weeks were lost through non-delivery of ties, so that the average rate of progress was 1¾ miles per week of six working days. The number of men employed in (*a*) clearing track 66 feet wide, (*b*) grubbing central width of 10 feet, (*c*) plowing, harrowing, and rolling the same, (*d*) track laying, (*e*) lifting and packing ties, and (*f*) straightening track, never exceeded 65, with one team of bullocks (12), and one horse. Cost per mile for labor only, $630; wages for laborers, $2.50 per day; gaugers, $3.15. The plowing, harrowing, and rolling cost $75 per mile, and is included in the $630. The total cost was under $15 per lineal foot. The best day's work was 2,772 feet, or 0.525 mile, and the best week's work a little over 2 miles. No ballast has been provided and no side or cross drains cut; the only water-ways are at well-defined and water-worn channels. The total timber bridging on the 36 miles is 1,108 linear feet, and only one box-drain has been put in. From 20¼ miles to 36 miles there is not a single water-way of any description.

The material train has never failed to run to the head of the road daily from the commencement of track laying, although there have been some very heavy thunderstorms with 1 to 2 inches of rain-fall in an hour. The track is laid with steel flange rails, 41¼ pounds per yard, 26 feet long, fastened to mild steel cross-ties, weighing 84 pounds each, 11 ties to a rail length. The average gross load of the material train is 100 tons. The locomotive employed is a six-wheel engine, built by Dübs & Co., of England; this description of engine has a greater average weight per foot of wheel base than any other class of locomotives in use in Queensland. The country passed through is believed to be the softest in wet weather to be found in Australia, but so far no trouble has been experienced with the line. The country is infested with white ants (termites), and ties of the best hard wood of the colony will not last more than three years in the form of ties. The government now in power are not very favorable to my system, but I hope to be able to induce them to complete the Croydon Railway on my system. I believe my system might be applied with advantage to your prairie country, subject to heavy rain-falls; that is to say, south of the snow regions.

The steel tie and special construction of track, as already described, was designed by Mr. Phillips with a special view to its adaptability for economical construction and maintenance, particularly for up-country lines. He is an advocate of a simpler form of construction for such railways, in suitable country, than that generally employed, and he thinks that this is rendered possible when "such a very superior article as a metal tie is used, which can be pressed into any desired shape." His system is peculiarly adapted to conditions existing on the Australian continent, the country being generally very even, and not subject to snow-fall. Mr. Phillips thinks that it would also be applicable in the more southern parts of the western plains of the United States, and in Mexico over even country which is liable to heavy floods. The more or less open ends of the ties are an essential of this system, on account of providing for the drainage of the earth in which the ties are embedded and packed. On the experimental line no tendency to lateral displacement was observed on a curve of 660 feet radius. If, under any other circumstances, such a tendency shall be observed, it would probably be met by using a transverse web inside at the middle of the tie. In regard to a suggestion that the use of bolts would be cheaper, by reducing the shop work, it has been stated that the difference in cost would be small, and that rivets are preferred as giving a more exact and accurate gauge. The outer clips are bolted on templets while being riveted, so as to insure accuracy in fitting. No ballast is intended to be used with this system of track, the ties being simply packed with surface soil. The Phillips ties for the Fassifern line were the first metal ties manufactured in Australia. Up to October, 1888, no ties of the type having a strip of extra thickness along the top table had been manufactured, owing to delays caused by the political circumstances already referred to.

This system is only applicable to level country. The principle which the inventor works upon is that surface soil, when subjected to compression, will sustain a very much greater weight than when loose or in its normal condition, and he instances the fact that well-beaten roads in soft country remain firm even when entirely covered with water. The effect of the passage of trains will be to compress the soil along the line, and the natural surface drainage can escape under the rails and between the ties; in certain cases cross drains may be used. The life of the tie is estimated as at least thirty years.

NEW SOUTH WALES.

New South Wales Government Railways.—The lines in this colony are of standard gauge, 4 feet 8½ inches. In July, 1888, there were 2,102 miles in operation and 66 miles under construction. The number of wooden ties used during 1887 was 77,451; of this number 66,407 were for renewals and 11,044 for new side tracks, etc. Mr. E. M. G. Eddy, the chief commissioner of railways, states that experience with metal ties in that colony has been too limited to allow of any opinion of value being given yet. I have not received any particulars of such limited experiments as have been made.

Mr. George Cowdery, one of the engineers of the government railways, has designed a steel cross-tie, which is fitted with a tie-plate at each end to give the rails the usual inward inclination and to compensate for the weakening of the tie by the stamping of lugs or clips up from the top table. A stud-bolt secures the rail and tie-plate to the tie, and a split taper steel key is driven between the rail and the head of the bolt.

VICTORIA.

Victoria Government Railways.—At the end of 1888 there were 2,167 miles of railway in operation in this colony. These lines are of 5 feet 3 inches and 3 feet 6 inches gauge. The maximum grades of the different lines range from 1 in 23 to 1 in 206, but average 1 in 40 to 1 in 50. The average cost per mile for construction, exclusive of rolling stock, has been from $124,880 to $396,370 for double track, and from $16,130 to $79,660 for single track. The blue-gum ties used cost 96 cents each. The agent-general in London states that he does not know of any metal ties being used.

NEW ZEALAND.

At the end of 1888 the colonial government owned 1,751 miles in operation, and there were also 92 miles owned by companies. The lines are of 3 feet 6 inches gauge. The agent-general in London states that metal ties are not used, and that it is not likely that the use of wooden ties will be abandoned. Mr. J. P. Maxwell, the general manager of the government lines, states that there is an abundance of durable timber available. The wooden ties are 7 feet by 7 inches by 5 inches, cost 48 to 96 cents each, and have a life varying from ten to twenty years.

TASMANIA.

In June, 1889, there were 375 miles of railway open to traffic, of which 171½ miles were private lines, the remainder belonging to the colonial government. The gauge is 3 feet 6 inches. The agent-general in London states that metal ties are not used and are not likely to be used.

Mr. Fincham, M. Inst. C. E., engineer-in-chief of the government railways, writing in June, 1889, stated that no metal ties are used in the colony, as there is an abundance of excellent timber, which enables the government to obtain ties 6 feet 6 inches by 9 inches by 4½ inches at prices from 36 to 48 cents each, including long carriage.

SUMMARY OF METAL TRACK FOR SECTION NO. 3.

	Miles laid with steel ties.	Total mileage.
South Australia	146	1,824
Queensland	40	2,103
New South Wales		2,168
Victoria		2,167
West Australia		160
New Zealand		1,843
Tasmania		375
Total	186	10,640

SECTION 4.—ASIA.

INDIA.

Railway mileage.—The following table is condensed from a table in the administration report on "The Railways of India" for 1888–'89, by Lieut. Col. L. Conway-Gordon, R. E., director-general of railways. The figures represent conditions at the end of March, 1889:

The railways of India.—(*March* 31, 1889.)

Railways.	Gauge.		Total authorized.	Total open.	Total double track.
State imperial.	*Ft.*	*In.*	*Miles.*	*Miles.*	*Miles.*
East Indian	5	6	1, 513. 25	1, 513. 25	474. 25
Patna Gya	5	6	57. 25	57. 25	....
Dildarnagar Ghazipur	5	6	12. 00	12. 00	....
Rajputana Malwa	3	3⅜	1, 672. 50	1, 664 50	1. 25
Bengal-Nagpur	5	6	827. 00	293. 00	....
Southern Mahratta	3	3⅜	1, 041. 75	854. 00	....
Southern Mahratta (Mysore section)	3	3⅜	296. 25	219. 75	....
Indian Midland	5	6	679. 25	514. 50	....
Villupuram Dharmavaram	3	3⅜	383. 75	82. 75	....
Bezvada extension	5	6	21. 50	21. 50	....
Dhond Manmad	5	6	145. 50	145. 50	....
Bhopal Itarsi (British section)	5	6	13. 00	13. 00	....
Total in the hands of companies	......		6, 663. 00	5, 391. 00	475. 50
Northwestern	5 3	6 3⅜	2, 396. 50	2, 381. 25	2. 25
Sind-Pishin, Chaman extension	5	6	27. 00	....	....
Oude and Rohilkund	5	6	739. 25	692. 25	....
Bengal Central	5	6	125. 25	125. 25	....
Wardha Coal	5	6	46. 50	46. 50	....
Jammu and Kashmir (British section)	5	6	8. 75	....	....
Toungoo Mandalay extension	3	3⅜	223. 50	222. 00	....
Total in the hands of the State	....		3, 566 75	3, 467. 25	2. 25
State provincial.					
Bareilly Pilibhit	3	3⅜	36. 00	36. 00	....
Total in the hands of companies	....		36. 00	36. 00	....
Eastern Bengal	5 3 2	6 3⅜ 6	770. 00	673. 25	29. 25
Nalhati	4	0	27. 25	27. 25	....
Tirhoot	3	3⅜	273. 25	273. 25	....
Lucknow-Sitapur-Sihraman	3	3⅜	124. 00	106. 00	....
Jorhat	2	0	30. 75	30. 75	....
Cherra Componyganj	2	6	15. 00	7. 50	....
Amritsar-Pathankot	5	6	64. 75	64. 75	....
Burma	3	3⅜	335. 75	333. 00	....
Total in the hands of the State	......		1, 640. 75	1, 515. 75	29. 25

The railways of India.—(*March* 31, 1889)—Continued.

Railways.	Gauge.		Total authorized.	Total open.	Total double track.
Guaranteed companies.	Ft.	In.	Miles.	Miles.	Miles.
Madras	5	6	839.25	839.25	42.50
South Indian	3	3⅜	654.50	654.50	....
Great Indian Peninsula	5	6	1,288.25	1,288.25	323.75
Bombay, Baroda, and Central India	5	6	461.00	461.00	60.00
Total guaranteed companies	....		3,243.00	3,243.00	426.25
Assisted companies.					
Darjeeling-Himalayan	2	0	51.00	51.00	....
Tarakeshwar	5	6	22.25	22.25	....
Deoghur	3	3⅜	4.75	4.75	....
Dibru-Sadiya	3	3⅜	77.50	77.50	....
Bengal and Northwestern	3	3⅜	510.25	276.25	....
Rohilkund and Kumaon	3	3⅜	54.50	54.50	....
Delhi, Umballa and Kalka	5	6	162.00	....	....
Thaton-Duyinzaik	2	6	8.00	8.00	....
Total assisted companies	....		890.25	594.25	....
Foreign.					
Pondicherry	3	3⅜	7.75	7.75	....
West of India Portuguese	3	3⅜	51.00	51.00	....
Total foreign	....		58.75	58.75	....
Native States.					
H. H., the Nizam's guarantied	5	6	489.25	329.25	....
Khamgaon	5	6	7.50	7.50	....
Amraoti	5	6	5.50	5.50	....
H. H., the Gaekwar's	2	6	71.25	58.75	....
H. H., the Gaekwar's, V. M. H	3	3⅜	64.50	27.50	....
H. H., the Gaekwar's, A. P	5	6	22.50	....	....
Bhopal Itarsi (Native State section)	5	6	44.00	44.00	....
Total in the hands of companies	....		704.50	472.50	....
Bhavnagar G., J., Porbandar	3	3⅜	328.75	259.75	....
Morvi	2	6	93.00	68.00	....
Jodhpore	3	3⅜	123.75	123.75	....
Rojpura Bhatinda	5	6	113.25	15.25	....
Kolhapur	3	3⅜	28.75	....	....
Jammu and Kashmir (Native State section)	5	6	16.00	....	....
Total in the hands of the State	....		703.50	466.75	....

SUMMARY.

Railways.	Total authorized.	Total open.	Total double track.
State Imperial.	Miles.	Miles.	Miles.
In the hands of companies	6,663.00	5,391.00	475.50
In the hands of the State	3,866.75	3,467.75	2.25
State provincial.			
In the hands of companies	36.00	36.00	....
In the hands of the State	1,640.75	1,515.75	29.15
Guaranteed companies	3,243.00	3,243.00	426.25
Assisted companies	890.25	594.25	....
Foreign railways	58.75	58.75	....
Native States.			
In the hands of companies	704.50	472.50	....
In the hands of the State	703.50	466.75	....
Total	17,506.50	15,245.25	933.25

GENERAL REMARKS (*Forms of metal ties*).—Experiments with various types of metal ties have been made during the last twenty-years on different lines, the first trials having been made on the State railways, about 1873, and some of these types have been in service for a sufficient time to enable reliable data to be gathered and conclusions drawn as to their merits in point of efficiency and economy. The principal types used may be divided into the following classes: (1) Cast-iron and steel bowls and cast-iron plates (all arranged in pairs and connected by the rods or tie-bars; (2) Wrought-iron and steel cross-ties. Various forms of these types have been used and various methods of rail fastenings have been tried with them, while the different systems of track have been tried under various conditions of road-bed and traffic. Large orders for cast-iron plate ties and steel ties are given out from time to time for the State and private lines. The cast-iron bowls are said to be becoming obsolete, having been found unsuitable under fast traffic; although they have done good service in the past, they are not being used much now on new work, and on lines where they have been in use they are gradually being replaced. One objection to them is the difficulty of getting them properly packed with ballast so as to keep the track in proper line and surface. Sand is the only satisfactory material, but it must be covered with stone or other coarse material to prevent dust, and it is liable to be washed out. The cast-iron plate ties ("Denham-and-Olpherts" type) have given very excellent results and are in extensive use, while large numbers are being manufactured. Until recently these plate ties were nearly all imported from England, but are now being manufactured by at least two iron works in India, at Jamalpur and Burraakur; the home manufacture seems likely to become an important industry. Details of the manufacture are given elsewhere. Another type of tie which has been extensively used within the last few years, and which is giving satisfactory results, is the steel cross-tie designed for the lines of the State railways system, and used for lines of 1 meter gauge and the Indian gauge of 5 feet 6 inches. They have been used on frontier lines with heavy traffic, and appear to be the standard type of the future.

The following is from a communication from Mr. T. W. Jones, of the East Indian Railway, dated in October, 1889:

> Very few metal ties are used on our meter-gauge lines; most of them use sal or deodar wood. I have had charge of from 70 to 100 miles of track for the last twenty years, and have had experience with oval and round cast-iron bowls, Barlow's longitudinals, Denham ties, and three patterns of Denham-Olpherts ties. Bowls do well in side-tracks, but are not suited for high speeds, as when well packed they make a very unyielding track, while, if loosely packed, they break. Barlow's system is a longitudinal with two chairs cast on it, and an angle-iron tie bar is bolted to the plates at the middle; these also do well in side-tracks, but break lengthwise, under the rail, when run over at high speed. The Denham cast-iron plate ties give good results but have three weak points: First, the wooden key for the rails; second, the wooden block under the chair; third, the tie-bar, which does not hold the rails together after the plates break. It can, however, be packed with any sort of ballast,

and makes a smooth track; the number of breakages is also very small. I have had experience with all classes and weights of the Denham-Olpherts cast-iron plate ties, and think the present shape is far the best cast-iron tie that has been made up to date. The first Denham-Olpherts tie was of a much lighter section, and the rail instead of being suspended, as now, by the top-table, rested on wooden blocks; as the blocks became crushed and also on account of the lightness of the outer jaws, the number broken in the first year was larger than it is now. This explains the average of .84 per cent. on page 15 of your report [preliminary report; Bulletin No. III—E. E. R. T], although I have never heard of the percentage being more than .70 per cent., and this only where light plates were used and the men were careless. The average now is about .40 per cent., I believe. The Indian Midland Railway has only used the latest type, and this explains the small number of breakages on that line. Bowls of corrugated steel have been largely used on the Oude and Rohilkund Railway, where they are packed with sand; but although better than the cast-iron bowls, they are not satisfactory where the speed is high and rolling-stock heavy. Tozer's steel cross-tie (see England) has been used on some of the state lines with double-headed rails. With flange rails a steel cross-tie similar to that in use on the Northeastern Railway of England has been tried. This latter type has been adopted as the standard on the new Bengal-Nagpur Railway, but engineers of experience are of opinion that the metal will soon be rusted away, especially on the sandy plains, where there is a good deal of salt in the earth.

The advantages of using the Denham-Olpherts ties in India are as follows: (1) Every part can be made in the country by uneducated native workmen, and without very expensive machinery, at a lower price than is paid for good, hard wood ties. The cost of good sal ties is 5 rupees to 5 rupees 4 annas ($1.67 to $1.75); chairs, spikes, keys, etc., 48 cents, or a total of 6 rupees, 8 annas to 6 rupees 12 annas ($2.16 to $2.24) per tie, while the metal tie costs 5 rupees 8 annas ($1.83) complete. The wooden ties when removed from the track can be sold for 8 to 16 annas, while the cast-iron ties, which cost 55 rupees ($18.33) per ton when new, are worth 30 rupees ($10) per ton as scrap; a new tie can almost be made out of the remains of an old one. At present we have no appliances for working up old steel ties into new ones. (2) There is no danger from fire, and in a country where on a May morning three or four ties sometimes catch fire on a mile of track, this is an important point. (3) There are no wooden keys to keep tight or renew. (4) There are no spikes to work loose or break, or for the villagers to steal. (5) The gauge is always preserved and does not require constant adjusting. I find that Denham-Olpherts ties require to be carefully packed at least three times before the ballast is boxed up. In this respect they are at first a little more trouble than wooden ties, but once they get a good bearing they stand three times as long as wooden ties. The rails do not creep nearly as fast where Denham-Olpherts ties are used, and the lower table of the rails does not get marked or indented as on track where it is supported in chairs, and it is consequently available for service after the upper table is worn out. About two years ago a young inspector on a state railway, who was then using Denham-Olpherts ties for the first time wrote to me in great distress; the ballast was very poor, and he said that do what he would the ties were continually loose. I replied that a little patience was necessary and that when once he had his Denham-Olpherts ties properly bedded he would find little trouble with them and could reduce his maintenance gangs. Twelve months later he wrote again, saying that his down track, which was laid with the Denham-Olpherts ties, gave 25 per cent. less trouble than the up-track, which was laid with wooden ties, and he only wished the chief engineer would allow him to relay the up-track. The saving in labor is even more apparent after the fourth year when a track on wooden ties begins to need a lot of repairs, unless the renewal of ties has gone on systematically and carefully all the time. Even where wooden ties are changed monthly, there is generally an extra large number to renew after a certain period and this continual pulling about of the track does not conduce to smooth running. During the hot months it is almost impossible to keep wooden keys in the chairs, even with a man to every 2 miles of rails; and the villagers being very fond of iron spikes, which they find useful for making agricultural implements, a great number are stolen annually; I have known 200 taken in one night from a mile of track. This explains why I prefer metal ties.

We use the hardest stone procurable, broken from three-fourths inch to 2 inches diameter, or cube, for ballast, and when a road is laid with at least 6 inches of this under the ties, the Denham-Olpherts tie gives as elastic a track as can be desired. Most cast-iron ties are unpleasantly rigid, and thus damage the rolling stock. One of the gravest defects in many of the steel ties used with flange rails is that a rail can not be renewed without bending one of the clips, which fit over the flanges, and this forcing of the clips upwards often results in breaking them and the tie is then comparatively useless. With mild steel this ought not to occur, but there is no gainsaying the fact that large numbers may be seen which have been damaged in this way. One type of tie did not admit of the rail being taken out at all, and the only way in which a defective tie could be removed was by taking off the fish-plates, slewing the rails out of line, and then slipping the ties off the end one by one. Most of the steel ties are also made of metal far too thin for the heavy strains which ties have sometimes to bear, when improperly packed or when owing to the bank sinking they are left partially unsupported. Of course this is done to lower the price, but such ties can not be economical, and railway engineers would do well to refuse to have anything to do with ties which are only three-eighths inch thick. Plates one-half inch thick give much better results and are cheaper in the end.

Ballast for metal ties.—Different materials have been used; sand, gravel, burnt clay, broken brick, and broken stone; the first two are principally used with metal ties. According to a paper on Stone ballast in India, in the Railroad Gazette, New York, May 3, 1889, the cast-iron bowls were not found suitable for fast traffic on account of their making a very rigid road and the large number of breakages. For packing these bowls, fine sand was generally used, and in some cases where they were packed with gravel or broken brick the results were very bad, "from 25 to 40 per cent. having failed in two years under moderate traffic." Where sand was used an upper layer of brick or stone about 3 inches thick was found necessary in order to prevent the sand from flying up and damaging the machinery and bearings of the engines and rolling stock. In one or two cases where hard stone 1 to 1½ inches in diameter was used, very good results were obtained, and the track was more elastic than with sand or any other description of ballast. The Denham-Olpherts cast-iron plate ties are usually packed with hard stone ballast, but where double-headed rails are used (the rails being suspended by the head instead of resting in the chairs) the track is as elastic as track on wooden ties. Sand, gravel, and stone are used with the steel cross-ties.

Wooden vs. metal ties.—The wooden ties used are mainly of imported creosoted fir, or of native sâl or deodar, the sâl being the best for the purpose. There has naturally been considerable controversy over the respective merits of wooden and metal ties, the former being indorsed by some few engineers, but mainly by parties interested in private forest properties. The testimony of numerous eminent and practical engineers in favor of the latter, and the steady increase of their use after years of experiment and experience, brings the balance of competent opinion decidedly in favor of the metal ties. In February, 1888, the following prices were given by a correspondent of Indian Engineering, a Calcutta paper, the prices for the wooden and cast-iron ties being those of the East Indian Railway and that of the steel ties of the Oude and Rohilkund Railway: Sâl and deodar ties cost 5 rupees ($1.66) and 3 rupees 8 annas ($1.16) each, respectively; but as the iron chairs and fastenings cost 1 rupee 13 annas 9 pice (60 cents), the total cost per tie was 6 rupees 13 annas 9 pice ($2.26) and 5 rupees 5 annas 9 pice ($1.76) each, respectively. The Denham-Olpherts cast-iron plate ties cost 5 rupees 13 annas ($1.91) each complete, and the steel ties 9 rupees 4 annas ($3.05) each, imported. The average life of a deodar tie is about ten years and of sâl about eighteen years; other authorities give the life at twelve years for sâl, seven years for deodar, and five years for creosoted pine. The number of renewals has been put at about 10 per cent. per annum for wood and 1 per cent. per annum for Denham-Olpherts iron ties. Jungle-wood ties have been tried on the Rohilkund and Kumaon Railway, but the wood was found unsuitable for this purpose, as it can not stand exposure to wet and rain, and decays very rapidly. At the beginning of 1887 there were 70,000 of these ties in the track, but during that year 21,000 were renewed, and in the first half of 1888 over 17,000 were renewed, that is to say, in eighteen months more than half the ties on the line had been renewed. Sâl was used in place of the jungle wood, and the company's report of November, 1888, stated that there were at least 5 sâl ties under every rail. The weight of the heaviest wooden tie, with chairs, spikes, etc., complete, is about 240 pounds; and of deodar ties 180 pounds.

It has been claimed that in case of derailment there is likely to be less damage to track and rolling stock if the accident occurs where wooden ties are used than would be the case where metal ties are used; while this may be true to some extent, the metal tie is likely to give a better and safer track and less liable to derailment than a wooden tie. European experience has shown that a steel-tie track can be made to withstand derailments, and the Sind-Pishin Railway in India has put in a hydraulic press for reshaping steel ties, and steel ties damaged in this or other ways, have been repaired at small cost and put in service again.

The following comparative estimates of the cost and expenses of wooden and metal ties appeared in the Indian Engineer during 1888. The first is for deodar wood and Denham-Olpherts cast-iron ties in main track; and the second is for sâl wood and cast-iron bowls for sidings.

	Rupees.	United States currency.
No. 1 (wood).		
1,760 deodar ties, with fittings, at 5 rupees 1 anna	8,910	$2,970.00
79,200 cubic yards ballast, at 5 rupees per 100	3,960	1,320.00
	12,870	4,290.00
Less value of 1,760 fire-wood ties, at 4 annas (8 cents), when taken out of track	440	146.66
Balance	12,430	4,143.34
No. 1 (iron).		
1,760 Denham-Olpherts ties, complete, at 6 rupees	10,560	3,520.00
55,440 cubic feet of ballast, at 5 rupees per 100	2,772	924.00
	13,332	4,444.00
Less value of 3,520 plates and 3,520 jaws when broken, less 5 per cent. for loss of small pieces = 148½ tons, at 30 rupees ($10.)	4,455	1,485.00
Balance	8,877	2,959.00

This shows a saving of 3,553 rupees ($1,184.34) per mile by using iron instead of wooden ties, supposing the life of each to be the same; but as the former will last at least twice as long as sâl, and three times as long as deodar, the economy is still greater.

	Rupees.	United States currency.
No. 2 (wood).		
1,600 sâl ties, at 5 rupees each	8,000	$2,666.66
3,200 cast-iron chairs (21 pounds) 8 annas each	1,600	533.34
6,400 wrought-iron spikes at 1 anna each	400	133.33
Total	10,000	3,333.33
No. 2 (iron).		
1,600 bowl ties, complete, at 7 rupees each	11,200	3,733.33
Extra cost of laying	100	33.33
Total	11,300	3,766.66

The saving in first cost would, therefore, be 1,300 rupees ($433.33) per mile in favor of the wooden ties. Under the most favorable conditions the cost of the track with wooden ties for 50 years would be as follows:

	Rupees.	United States currency.
First cost	10,000	$3,333.33
Two renewals, 1,600 by 2 new ties, at 5 rupees	16,000	5,333.33
Total	26,000	8,666.66

The value of the wooden ties taken out would not more than pay the cost of labor in taking out the old and putting in new ties, and may therefore be left out of consideration. The cost of the track with iron ties for the same period would be 11,300 rupees ($3,766.66) per mile for first cost and labor, or a total saving of 14,700 rupees ($4,900) per mile in favor of the metal ties. In such side-tracks, except in case of accident, the life of these metal ties may be estimated at fifty years, while wooden ties require renewal every twelve or fifteen years, it being an undoubted fact that white ants, wet and dry rot, etc., destroy wooden ties much faster in sidings than in the main track.

There are materially different conditions in different parts of so large a country; but, speaking generally, wood is not procurable in quantity as a rule, and must therefore be transported from one section to another to a certain extent. In Bengal wooden ties last about five years, as they soon split under the intense heat and rot during the rainy season. In Burmah iron-wood and teak ties are used; the former is not attacked by the white ants and is little affected by dry rot, the latter is softer and lasts about 8 or 10 years. Native hard and soft woods cost too much and are not obtainable in sufficient quantity; imported creosoted pine is cheaper but not durable. The tropical climate is hard on wood, and the white ants destroy large quantities of timber in a very short time. Metal in some form or other is surely taking the place of wood. Sir A. M. Rendel, consulting engineer of state railways, states that the cast-iron plates and steel crossties, though dearer in first cost than imported Baltic timber, and in Upper India than sâl or deodar, are cheaper in maintenance than any kind of wood. Metal, taking durability into account, is certainly more economical, and in Bengal steel ties are used for cheapness and because timber is not procurable with facility or in sufficient quantity. The advantages of metal are eminently in economy. Comparisons made by engineers on the state railways between tracks with metal and tracks with wooden ties show decidedly in favor of the former. But metal ties are also more efficient, and one of these engineers stated in his report that, in his opinion, metal ties should be used in preference to wooden ties even if the latter were obtainable sufficient in quantity and quality at the existing prices. It is difficult to obtain a large and regular supply of wooden ties, and the price of timber is said to have been doubled during the last twenty years.

Tie-bars.—When separate pieces are used, connected by a transverse tie-bar or tie-rod, as in the case of cast-iron bowls or plates, experience has shown that each pair should be so connected. In the case of floods on the Northwestern Railway in November, 1887, at a part where only the alternate pairs of bowls were connected by tie-rods, the sinking or softening of the embankment allowed the disconnected bowls to part when the weight of an engine came upon them, and a train was thereby derailed and wrecked. After that it was decided to put a tie-bar to every pair of bowls.

Bowl-ties.—In The Indian Engineer, January 16, 1889, it was stated that about twenty-three years previous this type of track was not in favor on the Madras Railway, and large stocks were allowed to lie on the beach at Royapuram for months together; now it is the standard for the whole line. More than twenty years ago the East Indian Railway Company found that this same form of tie was unsuited for a line with high speeds and heavy loads, and they were either replaced by some other type or used in sidings only; in the face of this the Great Indian Peninsula Railway still adheres to it as its standard tie, and is not only using it for maintenance, but also on the doubling of the line which is being pushed on vigorously. The Indian Midland Railway is also using it, and the Sind, Punjab, and Delhi section of the Northwestern Railway is still laid with bowls for some distance, although in this part of the country they are not held in such high estimation as formerly. The Oude and Rohilkund Railway is now using a bowl-tie of corrugated steel. Mr. Ernest Benedict, in a paper on Metal Sleepers for Railways, read before the Institution of Engineers and Shipbuilders, Glasgow, Scotland, in March, 1877, mentioned the following roads as using cast-iron bowls: Madras Railway, 800 miles; Oude and Rohilkund Railway, 444 miles; Great Southern of India (South Indian), 86 miles; Scinde, Punjab, and Delhi Railway; Bombay, Baroda, and Central India Railway; East Indian Railway; Eastern Bengal Railway; Calcutta and Southeastern Railway.

The Government, in 1875, decided against cast-iron bowl sleepers (ties) on the Madras Railway and in Bengal, on the ground of their extra cost as compared with wooden sleepers. They, however, made a proviso that if iron sleepers could be made in India of native iron this conclusion might be reversed. The question of the comparative advantage of wooden and iron sleepers should, they said, be treated from a purely financial point of view; that is, all payments whether in first cost, renewals, or interest on both, should be taken as part of the money spent on the sleepering. Supposing the bowls to last twenty-four years, the total amount spent on them (including prime cost, renewals, and interest) would come to 36,846 rupees a mile at the end of the twelfth year, and 74,063 rupees at the end of the twenty-fourth year. Taking the bowls to last fifty years, the figures would be 32,734 rupees and 62,574 rupees. With wooden sleepers lasting twelve years, the cost would be 23,530 rupees and 52,551 rupees, respectively.

Mr. Benedict believed at that time in a comparatively small bowl, of circular form, with the bearing in the center; plenty of these ties to be used and each pair connected by a tie-bar. He considered them stronger, handier for the natives, and more firm in the ballast. While they had not been tried on lines with very heavy traffic, he believed they would answer on all other lines, and in side tracks would be practically everlasting. In regard to the white ants, he stated that they work in a covered way of clay; they could not bear the shaking of a railway which destroyed their covered way, and, therefore, did not attack ties in the main track.

In some cases the bowls were found to make too rigid a track, and in some rock cuts it became necessary to put a greater depth of ballast under them.

Manufacture of ties in India.—Cast-iron ties are now manufactured at the Burrakur Iron Works, Burrakur, Bengal, and at the works of the East Indian Railway Company, at Jamalpur, Bengal. The engineering press advocates the establishment of more extensive works, so as to make the manufacture of ties and other material for railways and general use a home industry, instead of importing so largely from England as at present. There is abundance of good ore, with coal and limestone, all practically unworked, while thousands of tons of cast-iron ties are brought from England every year, and the railways have large stocks of old rails on hand. Experience at the railway shops and foundries has shown that native labor can be utilized. The Government has been urged to assist in this enterprise, and there have been propositions to establish steel works at Burrakur. The Burrakur Iron Works supply pig-iron and manufacture large quantities of railway chairs and ties. In February, 1888, it was reported that they were carrying out a large order for Denham-Olpherts plate ties, at the rate of 10,000 per month. The prices of chairs and ties was about 3 rupees, 8 annas per 112 pounds (about 97 cents per pound); or 55 to 58 rupees ($18.33 to $19.33) per ton. From Mr. Ritter von Schwarz, superintendent of the works, I have received a very full report. Jamalpur is practically a railway town, having the works of the railway company, while the majority of the inhabitants are employed in the offices or workshops. At the foundries, attention has been given to the production of the Denham-Olpherts plate ties, the company using its own scrap, supplemented by pig-iron from the Burrakur Iron Works. About 10,000 tons of castings have been worked up into 100,000 of these ties. During the year ending March 31, 1889, 100,000 of these ties were made, and the men were then at work on a number for the Patna-Gya Railway. At the end of 1888, the shops turned out 400 or 500 complete ties per day. A large quantity of the Burrakur iron was used, the use of imported iron having been suspended. The wrought-iron for the tie-bars, keys, etc., is made from old rails and other scrap, and rolled by the company's rolling-mill, which is said to be the only one in India and is worked with marked success. Having found that considerable economy would result from manufacturing the ties for its own lines, the company has engaged an inspector from England to superintend the work and to carry out the tests required by the specifications adopted for similar ties manufactured in England.

Cast-iron vs. *steel ties.*—There is naturally considerable difference of opinion between the advocates of cast-iron and steel ties, and the matter of breakages and damages to track in cases of derailment of trains is one of the disputed points. A correspondent of Indian Engineering, March 24, 1888, stated that in February, 1888, a spare tender was derailed at a crossing and dragged for 200 feet over a track laid with Denham-Olphert's cast-iron plate ties without doing any damage; the track was fully ballasted. He also instances a case in which the middle car of a train was derailed and dragged nearly one-fourth of a mile over a track laid with wooden ties; every deodar and fir tie was damaged, many being broken in two, and having to be taken out; the track had been opened out for repairs, and the ties were uncovered. In this connection it should be noted that, while accidents are among the points to be considered, they are of comparatively minor importance to the question, and it must be remembered that the results of accidents are very variable. In one case a derailed wheel may cause very little damage to the track, while in a similar case, and under apparently similar conditions the track may be practically destroyed. As a rule, cast-iron is not considered by engineers as a suitable material for such use in railway track, owing to its liability to fracture under sudden or heavy shocks; and, while under certain conditions, this material has given good results and has been extensively used, the general experience—including that of India—points to steel as the metal most suitable in every way for railway ties. The correspondent above referred to is an advocate of cast-iron ties, and claims that steel ties can not be made in India, have little if any value as scrap, and are difficult to tamp. He thinks the minimum weight of a steel tie should be 160 pounds. The future growth of industry in India may include the establishment of steel works, as noted in the preceding paragraph, and certainly the steel ties are very highly spoken of by competent authorities. It is said that the Indian Government has adopted the steel tie for the State and frontier lines, on account of the danger, from a military point of view, attending the use of cast-iron bowls. Experiments have shown that a road on the latter can be destroyed in a very short time with a few sledge-hammers. It would seem, however, that the same sledges might be used to knock out the key fastenings of the steel ties for a few rail lengths and the rails removed; but, of course, with cast-iron, the jaws would be knocked and the bowls cracked, rendering them quite useless. As regards the cast-iron plate ties, it is said that cracked plates have been kept in the track without showing any tendency to shift.

Steel ties.—The steel ties which are now so extensively used were designed by Sir A. M. Rendel, consulting engineer for State railways, and have given excellent results, while the key or wedge fastening used has proved very successful in service. The ties are of mild steel, and are manufactured by most of the large steel works in England. Mr. Rendel states that any danger from rust is very remote, and that the ties will stand under heavy traffic. Up to 1888 about 525,000 tons of steel ties had been sent out from England, and about 70,000 or 80,000 tons have been sent out since that time. An objection which has been made against some of these ties is that there is extra trouble in renewals; the arrangement of the clips or lugs is such that the rails have to be canted in order to fit the flange of the rail on to the seat, and the objection is that to renew one tie two rails must have the joints unfastened, the keys all driven out, and must then be lifted out; the old tie is then removed, the new one put in its place, the rails put back, keys re-driven and joints fastened. One way of avoiding this trouble is to bend back one of the lugs of the tie sufficiently to allow the tie to drop from the rail when the ballast is removed, but it is difficult to get a purchase on the lugs while the tie is in place. The trouble may be reduced by taking out one rail only, and then tilting up the free end of the tie until the other end can be slipped off the rail-flange. The objection does not, of course, obtain with ties which have the clips sufficiently wide apart to admit the rail-flange horizontally. The engineers of the roads using these ties have reported very favorably of them. (Notes of special reports will be found included in the matter relating to the Northwestern Railway, Southern Mahratta Railway, Sind-Pishin Railway, Nizam's Railway, and South Indian Railway.) Mr. Bull, of the Cuddapah-Nellore Railway, (Villupuram-Dharmavaram system), and Mr. Lyle, of Nizam's Railway, have suggested that small holes on the top, at the ends, would facilitate proper tamping. Sir Juland Danvers, in a paper on "The Progress of Railways and Trade in India," read before the Society of Arts, England, in March, 1889, said: "A steel sleeper is used and found very serviceable." Some steel ties of the "Post" type (Netherlands State Railways) have been designed for India, but not yet introduced.

Contracts for metal ties.—The following is a list of some of the contracts awarded during the last two or three years; it is by no means complete, or even approximately so, but will serve to show that these ties are now firmly established in India, and that the experimental stage has been passed, the ties being ordered from time to time like any other track material:

Indian State Railways: Steel ties, July 19, 1887, December 4, 1888; steel and cast-iron ties, August 27, 1889.

East Indian Railway Company: Cast iron plate ties, April 7, 1887, January 26, 1888, February 14, 1889, November 14, 1889; steel ties, October 31, and November 12, 1880.

Bengal and Nagpur Railway Company: Steel ties, May 23, 1887 (180,000), February 28, 1888, October 30, 1888 (216,000), June 4, 1889 (375,000).

Southern Mahratta Railway Company: Steel ties, November 28, 1888, April 17, 1889.

Indian Midland Railway Company: Cast-iron bowls, June 7, 1888.

Madras Railway Company: Cast-iron bowls, December 7, 1888.

South Indian Railway Company: January 31, 1888 (12,684 tons of cast-iron bowls), November 27, 1888 (23,965 tons of steel ties), February 5, 1889 (9,513 tons of cast-iron bowls), July 2, 1889.

Bombay, Baroda and Central India Railway Company: October 18, 1887, and February 11, 1889 (steel); July 9, 1889 (cast-iron).

Delhi, Umballa and Kalka Railway Company: February 27, 1889 (100,000 pairs of cast-iron plate ties.)

INDIAN STATE RAILWAYS.—About twelve or fourteen years ago, according to a statement by an engineer formerly connected with these roads, the state railways were using on the meter-gauge lines an iron rail 3.52 inches high, and weighing 40 pounds per yard; the fish-plates were 14½ inches long, weighing 1½ pounds. These rails were laid on ties of creosoted Norway pine, or Indian teak; these were spaced 34 inches, center to center, and 22 inches at joints. The most common metal ties then in use were the inverted bowls of cast-iron, with chairs cast on top; each pair of bowls was connected by a light wrought-iron transverse tie-rod. There was also a wrought-iron longitudinal support, with chairs bolted on top; the longitudinals were of inverted trough section, and were connected by wrought-iron tie-rods. In both bowls and longitudinals there were holes in the upper part, through which sand was poured and rammed to give a firm bearing. (Whether the longitudinals were used on the state railways is not definitely stated.)

A brief report, giving a summary of the trials of metal ties on these lines, was made in 1885 by Sir Guilford L. Molesworth, consulting engineer for state railways. His conclusions were in favor of bowls, or Denham-Olpherts plate-ties of cast iron, with vertical wedge fastenings, capable of alteration of gauge on sharp curves. Of other types he preferred the rolled wrought-iron Vautherin tie to the stamped steel MacLellan tie. Considerable progress has, however, been made since the date of his report, and the new steel tie has, as already stated, come into extensive use.

The first metal ties tried were Mr. Greaves' cast-iron inverted bowls, laid in 1873. They were laid on stone, broken small, and proved fairly satisfactory. (See plate No. 20.) A similar tie was laid on the Porada branch, without ballast, the soil of the embankment being earth and clay mixed. The plan answered well in a district where ballast would have been expensive. The "Greaves" bowls were of circular form, about 22 inches in diameter across the bottom, and 15 inches long on top under the rail. The depth under the rail was $4\frac{5}{8}$ inches; height $8\frac{1}{4}$ inches from the bottom of bowl to top of jaw of rail-chair; $9\frac{3}{8}$ inches from bottom of bowl to top of rail. The thickness varied from three-eighths inch to one-half inch, and the weight of each casting was 79 pounds. The rail chair was in the middle of the top, and on each side was a pocket in the metal for a wooden packing-piece, or cushion, $3\frac{3}{16}$ by $2\frac{1}{4}$ inches, and 1 inch thick, upon which the rail rested. In each bowl were two holes three-fourths inch in diameter, for tamping the sand-ballast. The rails were of double-headed section, $4\frac{3}{4}$ inches high, weighing 68 pounds per yard. Each pair of bowls was connected by a wrought-iron tie-bar 2 by one-half inches, and 7 feet $9\frac{3}{4}$ inches long; the bar was placed on edge and passed through each bowl, being secured by a gib on one side and a cotter on the other, passing through slots in the bar. A complete tie, therefore, consisted of two bowls, one tie-bar, two gibs and two cotters. The following was the weight per mile in tons of 2,240 pounds for 1,760 pairs of bowls:

	Tons.	Pounds.
Cast-iron in bowls	124	336
Wrought-iron in tie-bars, gibs, and cotters	21	1,344
Total	145	1,680

In 1876 a few cast-iron ties of De Bergue's patent were sent out from England and were tried experimentally on the meter-gauge. (See plate 20.) They consisted of a pair of shallow "saucers," placed bottom down, and connected by a wrought-iron tie-bar 2½ by three-eighths-inch, the upper edge of which engaged with a groove in the bottom of the "saucer," while the lower part projected down into the ballast. Flange rails were used, and were fastened by iron clamps bearing on the tie and the inner flange of the rail, with a hooked bolt passing through the clamp; the hook held the bottom of the tie-bar, and the nut was screwed down on the clamp. The weight per tie was 54½ pounds, and it was intended to use eight complete ties to a pair of 40-pound rails 21 feet long.

In the same year a few wrought-iron cross-ties of the "Vautherin" type were also tried experimentally on the meter-gauge. (See plate 20.) They were 5.9 feet long, about 2⅝ inches deep, 3⅛ inches wide on top, 6½ inches wide inside at the bottom, and about 9 inches wide over the bottom flanges; the thickness was about one-fourth or five-sixteenths of an inch. (These dimensions, except length, are measured from half-size lithograph drawings, and are therefore only approximate.) The ties were curved to a radius of 19.05 meters (62.5 feet), giving the rails an inward inclination of 1 in 20; they were curved as soon as they left the rolls, and the exact curve was afterwards given when the metal was cold. The weight was about 12 kilograms per meter, or 24.15 pounds per yard. The rails were of flange section, weighing 40 pounds per yard; the outside flange was held by a gib and the inner flange by a gib held in place by a vertical cotter, with a second gib or packing-piece inserted between the back of the cotter and the metal of the tie.

In 1878 two types of Livesey's wrought-iron ties were tried on the Western Rajputana line; one consisting of a pair of bowls of improved form, and the other consisting of a pair of corrugated plates of inverted trough section, the trough being parallel with the rails, with the corrugations at right angles with them. (See plate No. 20.) In both types the pieces were connected by tie-bars 1½ by three-eighths-inch, passing through and secured by a gib on the outer side and a cotter on the inner side of each piece. The gauge was 1 meter. The rails weighed 40 pounds per yard, and were generally secured to the bowls by a riveted clip on the outer side, and a bolted clip on the inner side; while to the corrugated plate-ties they were secured by two riveted clips on the outer side, and a bolted clip on the inner side; in some cases a gib and cotter fastening, similar to that of the Vautherin tie, was used. The patentee proposed to lay six complete ties to a pair of rails 21 feet long, and the weight of track complete was estimated at 40 tons per mile. These were reported upon unfavorably.

The MacLellan steel cross-ties used in 1882 were of similar type to the new standard steel ties, and were used for meter gauge lines with rails weighing 41¼ pounds per yard. They were 5 feet 3 inches long over all, each stamped from a plate 5 feet 6 inches long, 14 inches wide, and three-sixteenths inch thick. The thickness was uniform, but the cross-section of the tie varied; at the rail-seat it was flat for about 5 inches, 3½ inches deep, and 9½ inches wide over the bottom; at the middle it was of arched section 4½ inches deep and 8½ inches wide at the bottom, while at an intermediate point it was 4½ inches deep and 8¾ inches wide. The ends were bent to give the rails an inward inclination, and the extremities were closed by rounding off the top table. The fastenings were of the gib and cotter type, above described. The tie weighed 50 pounds and the fastenings 3½ pounds. The ties for lines of 5 feet 6 inches gauge were 8 feet 6 inches long, made from plates 8 feet 9 inches long, 15 inches wide, and seven thirty-seconds inch thick, the finished tie being three-sixteenths inch thick; the cross-section was nearly identical with the above, but at the rail-seat it was flat on top for a width of 6 inches, 9½ inches wide at the bottom, and 4 inches deep; the tie weighed 100 pounds, and the fastenings 5 pounds.

The cast-iron bowls designed by Mr. Molesworth in 1878 were for meter gauge lines with flange-rails, and were of a generally similar form to those first described (1873); they were 18 inches in diameter, with radial ribs on the outside; one flange of the rail was held by a projecting lug or jaw, and the other by a wrought-iron gib and cotter. The thickness was five-sixteenths inch in the web, and the depth inside was 3⅝ inches. The tie-bar was 2 by ⅜-inch and 5 feet 1 inch long; it was laid on edge, and passed through the bowls, being secured to each by a gib on the inner side and a cotter on the outer side of the track. An adjustment of one-fourth inch at curves could be obtained by reversing the positions of one gib and cotter, or one-half inch by reversing both gibs and cotters. The modification of 1882 consisted in the use of a vertical cast-iron gib and cotter fastening for the rails. The tie-bar was of wrought iron or steel, 1½ by ⅜ inch, and 4 feet 7⅜ inches long; it had notches thirteen-sixteenths inch wide by three-eighths inch deep, accurately punched to templet to give the gauge; a plug in a hole in the top of each bowl under the rail engaged with the notch in the bar; the faces of this gauge-plug were not vertical, and there was thus a difference of gauge according to the different positions of one or both plugs. By this arrangement the gib and cotter fastenings at the end of the tie-bar are dispensed with. These ties were tried on the Tirhoot Railway and the Fazilka Branch of the Rajputana-Malwa Railway.

The Denham-Olpherts cast-iron plate ties are described fully later on. Mr. Molesworth devised a modification, consisting in the use of a cast-iron wedge with one of its faces corrugated; this is driven between a fixed lug and the loose jaw which holds the inner flange of the rail. (See Plate No. 21). The shape of these wedges is such that when the corrugated face of each wedge in a complete tie is towards the middle of the track the gauge is 3 feet 3⅜ inches (1 meter); when one wedge is turned with its corrugated face to the outside of the track the gauge is three-eighths inch slack, and when both wedges are so turned the gauge is three-fourths inch slack. This arrangement has not been very successful, owing to the difficulty of accurate fitting in casting; while such fitting could probably be secured by careful work, the system is more complicated than the ordinary fastening. A simple plan, suggested by Mr. Schwarz, of the Burrakur Iron Works, is to use at the ends of the tie-bar gibs of different widths, arranged in offsets; the gauge would be tight or slack according as the gibs were put with the wide or narrow part in the slot.

In 1881 proposals were advertised for cast-iron bowls slightly different from those made in 1878 for the Patna-Gya Railway. They were oval in plan, 23½ inches long by 20½ inches wide on the bottom, 5 inches deep in the middle, 11 inches center to center of the wooden bearing pieces; the thickness was about ¾ inch. The tie-bars were 7 feet 10 inches long, 2½ by ½ inch, placed on edge, and secured by gibs and cotters driven horizontally. The rails were of double-headed section, secured between the jaws of the chair by a wooden key driven on the outside of the rail.

The new type of steel tie now in extensive use, and which is the standard metal tie of the state railways, is a cross-tie of rounded trough section, with closed ends, and having an extra thickness of metal in the top table; in its general form it resembles half a pea-pod. They are modified from the older type of MacLellan steel ties, to meet the objections made by Sir Guilford L. Molesworth, consulting engineer, as to the want of metal at the fastenings. They were first made for the frontier lines, but are now adopted for all classes of lines, both of meter gauge and the Indian gauge of 5 feet 6 inches. (See plate No. 22.) They are made of mild steel plates rolled flat to the desired thickness and then pressed or stamped while red-hot between dies in a press, which operation turns down the sides and shapes the ends (which are curved down and flared out), gives the rail-seat an inclination of 1 in 20 and presses out the two clips or lugs for each rail. The steel is specified to be equal to a tensional stress of between 26 and 31 tons per square inch, with a contraction of 30 per cent. of the tested area at the point of fracture. The space between the edges of the lugs is slightly narrower than the width of the rail-flange, so that the rail has to be canted or tilted to one side to put it into place. This has the disadvantage of preventing the removal of one tie independently of the rest of the track, as in order to take out one tie the two rails must be loosened for their whole length and tilted over, or one rail loosened and the tie tilted up. Each rail is secured by a taper key with a split end, which is driven between one of the lugs and the rail-flange overlapping the flange. They are usually on the outer side of the rail, but one or both may be placed on the inner side if the gauge is to be widened. After the key is driven the split end is opened with a chisel, to prevent the key from slacking back or working loose. The ties are dipped in a black-varnish solution. They are not patented.

For the 5 feet 6 inches gauge, the ties are made from plates 9 feet long and 15 inches wide, with the middle thirteen thirty-seconds inch thick for a width of 4½ inches, and the sides about seven thirty-seconds inch thick (specified to be of such thickness as will make the tie weigh 120 pounds). The finished tie is 8 feet 9 inches long; at the rail seat it is 9½ inches wide at the bottom and 4½ inches deep; at the middle it is 4⅞ inches deep and 8½ or 9 inches wide at the bottom, while at an intermediate point it is 4½ inches deep and 9 inches wide; the ends are 13 inches wide. The lugs are 3 inches long and the keys 8 inches long. The tie weighs 120 pounds and the keys 1 pound each, making a total of 122 pounds for each tie, complete. The rails are of flange section, $4\frac{15}{16}$ inches high, 4 inches wide over the flange, and weighing 75 pounds per yard. For the meter gauge the tie is made from a plate 5 feet 9 inches long and 14 inches wide, with the middle part three-eighths inch thick for a width of 4 inches, and the sides about three-sixteenths or one-fourth inch thick (specified to be of such thickness that the tie will weigh 69 pounds). The finished tie is 5 feet 6 inches or 5 feet 7 inches long; at the middle it is flat on top for a width of 4 inches, and the bottom width is 9½ inches; at the middle it is of arched section, 8½ inches wide at the bottom and 5 inches deep. The ends flare out to a width of 13 inches. The lugs are 3 inches long, spaced 2⅞ inches apart in the clear, and the keys are 6 inches long. The tie weighs 69 pounds and the two keys 1.25 pounds, making 70.25 pounds for the tie complete. The rails are of flange section, 3½ inches high, 3¼ inches wide over the flange, and weighing 41¼ pounds per yard. The price of the broad-gauge ties is said to be about 6 rupees ($2) each in India. It has been stated (The Indian Engineer, March 31, 1888) that after two or three years' experience the general opinion was that these ties were too thin, especially for the northwest provinces, where the soil and the ballast are of a peculiarly corroding character. Sir A. M. Rendel, consulting engineer in England for the state railways and guaranteed lines, who introduced these ties, prefers them to the cast-iron plates. In February, 1888, there were over 3,000 miles of this track (including Mexico), on lines of all descriptions as regards grades, curves, etc. They had been laid during the past ten years, but principally during the previons four years. The traffic was not then very heavy. The weight of the broad-gauge locomotives was up to 45 tons in all and 36 tons on three pair of wheels, which would be increased to 42 tons; the engines of the meter gauge lines had a weight of 24 tons on six coupled wheels. The ties are spaced about 3 feet apart center to center, or eleven to a rail length of 30 feet. The cost was then about $20 per ton delivered at a port in England, and the expense of maintenance had been very low. As to durability, it is known that steel ties in another form have lasted for sixteen years on the Oude and Rohilkund Railway without injury. All kinds of ballast are used, but gravel or fine sand is the best; the behavior of the ballast under the tie is very good, particularly during floods and rainy seasons. The road-bed is of ordinary type, generally well ballasted. There is no trouble with maintenance of track nor with the rail attachments, nor from breakages.

The following statement, showing the quantities and various descriptions of metal ties which have been sent to India for the state railways since 1874, by the India office, was furnished me in September, 1889, by Mr. Abercrombie Jopp, director-general of stores, India office, London.

Statement of iron and steel ties sent to India by the India office during years 1874 *to* 1889.

Description of ties.	Number supplied.	Miles of single track.
Meter gauge:		
DeBergue's system; cast-iron bowls ....pairs..	7,040	4
Vautherin; wrought-iron cross-ties ....number..	6,332	4
Cast-iron bowls ....pairs..	39,018	20
Wrought-iron bowls ....do ...	36,000	18
Wrought-iron cross-ties ....number..	286,000	143
Steel cross-ties ....do	723,829	361¾
Denham-Olphert's cast-iron plates....pairs..	347,000	173½
Total ties for meter gauge	1,445,219	724¼
Indian gauge (5 feet 6 inches):		
Cast-iron bowls ....pairs..	364,361	183½
Steel cross-ties ....number..	1,941,398	988½
Denham-Olphert's cast-iron plates....pairs..	245,347	122½
Total ties for 5½-foot gauge....	2,551,106	1,294½
Total of complete cross-ties....	3,996,325	2,018¾

East Indian Railway.—The line was originally laid almost entirely with wooden ties, but cast-iron plate ties are now extensively used. The Sinhgharon branch is laid partly with Greaves cast-iron bowls and partly with creosoted fir ties. Creosoted fir and sâl ties are used generally on the other branches. Cast-iron bowls have been used, but several years ago they were found unsuitable for a line with high speed and heavy loads, and they were afterwards only used in sidings. In 1877 Mr. Benedict, in a paper on "Metal sleepers for railways," read before the Society of Engineers and Ship-builders, Glasgow, Scotland, stated that thus far the bowls had not done well, but that a further trial would be made. The steel cross-ties have been used, but the standard metal tie on this road is the Denham-Olpherts cast-iron plate tie. In the company's report for the half year ending December 31, 1889, it was stated that the lavish expenditures during the past few years upon renewals of the line, replacing iron rails with steel rails and wooden ties by metal ties, were then taking effect, as there was no longer the heavy maintenance which had formerly burdened the road, and it was predicted that these maintenance expenses would continue to decrease with the gradual extending of the improvements.

The length of this system open for traffic on December 31, 1888 (exclusive of sidings), was as follows:

	Miles.	Feet.
East India Railway, proper	1,513	2,376
Tarakeshwar Railway	22	1,214
Patna-Gya State Railway	57	1,056
Ghazipur-Dildarnagar Prov. State Railway	11	5,239
Sindia State Railway	74	4,657
Total	1,677	3,982

The standard type of track consists of double-headed steel rails 30 feet long, weighing 75 pounds per yard, laid on Denham-Olpherts cast-iron plate ties weighing 227 pounds each; eleven ties to a rail length. The total number of these ties had increased from 413,000 at the end of 1882 to 1,311,000 at the end of 1887, the latter amount representing about 680 miles of track. At the prices of iron in April, 1888, the cost of track laid with these ties was less than that of a track on wooden ties. The breakages since 1885 averaged about .84 per cent. per annum. These ties are described in full farther on. (See plate No. 23.)

In January, 1888, the Government called for an exhaustive report on the behavior of the Denham-Olpherts plate-ties on various sections of the line, and also for the opinions of the engineers who had such ties in their districts. During the half-yearly inspection made in January and February, 1888, very careful examinations were made in order to form an opinion as to the relative merits of the track on cast-iron and on wooden ties, and in April, 1888, Major W. H. Coaker, deputy consulting engineer for railways, presented his report. He stated that the excessive oscillation complained of on some sections was due to the rounded shape of the head of the new rails and not to irregularity in gauge caused by the use of the metal ties, as had been alleged. On the whole he was of opinion that these plate-ties make an excellent track, and notwithstanding the use of stone ballast, which is generally unsuited for cast-iron ties, the track was fairly elastic, owing to the rail being suspended by its head: he advised the use of twelve ties instead of eleven to a 30-foot rail length, and this has been adopted in some cases where the rails are laid to break joint. As to irregularities in gauge, there is little difference between track on cast-iron and on wooden ties, as will be seen by the following summary of a number of gauge tests made early in 1888 and included in Major Coaker's report:

	Denham-Olphert's.	Wooden.
Tight	15	14
Slack	13	5
Correct	3	4
Varied	2	7
Total	33	30

In regard to the question as to the reported difficulty in insuring accuracy of gauge with the cast-iron ties, Mr. Denham, chief engineer of the railway and one of the inventors of the tie, stated that this was due, *First*, to letting separate contracts to different parties for the cast-iron and wrought iron work; *Second*, to faulty packing or tamping, as if tamped too much on the outside the plates will dip inwards and narrow the gauge, or if tamped too much on the inside the gauge will widen; this trouble can be avoided by having the work carefully done; *Third*, to the difficulty in manufacturing the pieces so as to render the gauge exact at all times, although careful work has reduced this source of trouble to a minimum. Mr. Denham, as one of the patentees, preferred not to make a statement of his opinions as to the merits and demerits of the tie, but sent in a number of reports from the district engineers. While differing in opinion and as to details, the impression given by these reports is that the ties are very satisfactory; rather frequent packing is required; but as there is not the trouble with the fastenings that there is with the wooden ties, the track-men have more time to attend to the packing, and the net result is a reduction of the maintenance expenses. The number of renewals is also very considerably reduced below that of wooden ties, effecting an economy of over 6½ per cent. per annum. The saving in maintenance on the Allahabad division is estimated at 821 rupees ($273.80) per mile per annum in favor of cast-iron over sâl ties; on this division there were in January, 1888, 276¾ miles laid with these ties; on 103½ miles the rails rest on wooden cushions, and on 173¼ miles they are suspended in the jaws of the chairs; the ties were first laid on this division in 1880 for a length of 5 miles.

The following table is taken from the report of the chief engineer, Mr. Denham, for the half year ending December 31, 1888, and shows a record of the tie work during that period:

	Ties in track, including sidings.		Removed.			Laid.	Removal on total.		Total removal of each class.
	July 1, 1888.	December 31, 1888.	Defective.	Other causes.	Total.		Defective.	Other causes.	
							Per cent	*Per cent*	*Per cent*
Wooden transverse:									
Fir (10 ft. by 10 by 5 in.)..No..	423, 793	394, 346	19, 622	12, 773	32, 395	3, 948	4. 63	3.01	7. 64
Sal (10 ft. by 10 by 5 in.)..No..	1, 597, 021	1, 560, 852	34, 868	39, 787	74, 655	38, 486	2. 18	2. 49	4. 67
Others......do..	896, 372	892, 909	11, 726	10, 422	22, 148	18, 685	1. 30	1. 17	2. 47
Total.....do..	2, 917, 186	2, 849, 107	66, 216	62, 982	129, 198	61, 119	*2. 26	*2. 16	*4. 42
Iron:									
Denham-Olphert's plate ties (227.37 lbs. each)..pairs..	1, 451, 076	1, 524, 999	5, 747½	1, 313	7, 060½	80, 983½	. 39	. 09	. 48
Denham's plate ties ... pairs..	82, 695	82, 621	78	58	136	62	. 09	. 07	. 16
Bowl ties (228 lbs. each).. pairs..	237, 592½	238, 095½	1, 147	72	1, 219	1, 722	. 48	. 03	. 51
Others .....No...	34, 448	34, 444	4	....	4	....	. 01	....	. 01
Total..........	1, 805, 811½	1, 880, 159½	6, 976½	1, 443	8, 419½	82, 767½	*. 38	*. 08	*. 46
Grand total ...	4, 722, 997½	4, 729, 266½	73, 192½	64, 425	137, 617½	143, 886	*1. 55	*1. 36	*2. 91

*Average.

The next table shows the total length of single track laid with wooden and iron ties on December 31, 1888:

	Wooden.		Iron bowl.		Iron plate.		Wood and iron and timber intermixed.	
	Miles.	*Feet.*	*Miles.*	*Feet.*	*Miles.*	*Feet.*	*Miles.*	*Feet.*
East Indian Railway proper	1,294	4,148	79	2,903	735	1,630	265	5,030
Other lines	101	1,329	....		26	5,051	59	3,231
Total	1,396	197	79	2,903	762	1,401	325	2,981

As already stated, the company has undertaken the manufacture of cast-iron-plate ties at its Jamalpur works, and early in 1888 the Burrakur Iron Works were turning out 10,000 of the same class of ties per month for this road.

The following is the substance of a detailed statement in regard to the Denham-Olpherts cast-iron-plate ties, which was sent to me in February, 1888, by Sir A. M. Rendel, consulting engineer. There were about 900 miles in all on the East Indian, Eastern Bengal, and branches, and further supplies had been ordered. The divisions laid with these ties were, as a rule, level and straight; the traffic was heavy and slow, hauled by engines weighing 40 to 44 tons, with 14 tons on each pair of wheels, say 28 tons on two pair and 40 tons on three pair of coupled wheels. A detailed description of these ties is given further on. They are spaced about 3 feet apart center to center of tie-bars. The plates, with their jaws, weigh 109 pounds each, or 218 pounds per pair; the tie-bar and accessories weigh 28 pounds. The cost for one tie complete, including tie-bar and fastenings, was then about $2.16, delivered at an English port. The labor of maintenance was normal and the breakages were not serious. The results as to durability have been good. Various kinds of ballast have been tried, including broken stone, brick, sand, and kunker (this latter is a kind of nodular limestone, commonly burnt for lime in India; it is rather soft). The road-bed is of ordinary construction, well ballasted, and the ballast behaves well under the ties. The rails are of double-headed sections, weighing 75 pounds per yard; the joints are suspended. The reason for adopting metal ties was that native hard or soft woods cost too much and were not obtainable in sufficient quantities, while imported creosoted pine was cheaper but not so durable. The general results are satisfactory, and there is no particular trouble with maintenance. As compared with wooden ties they are more durable but less elastic. Various kinds of wooden ties are used, but the tropical climate is very bad on timber, A good sâlwood tie, which is the best to be got in India and is sometimes very good, costs 5 rupees to 5 rupees 5 annas ($1.61 to $1.83.) Mr. Rendel prefers the steel cross-ties.

A cast-iron-plate tie designed by Sir Bradford Leslie, formerly chief engineer of the road, was used on a short branch line crossing the

Hooghly River and proved quite a success; it could be easily and quickly laid and had but few breakages. The plate is 24 by 17 inches, the greater length being parallel with the rail. There are two fixed jaws on the outer side of the track and a loose jaw on the inner side; this loose jaw has a projection which passes through a slot in the plate and straddles the tie-bar; it is held in place by a flat taper key driven through it and through webs on the rail chair. The plate has a segmental rib on the lower side with two transverse ribs or webs on each side. The tie-bar is 2 inches deep; it is set on edge and is under the plate, passing through a slot in the longitudinal rib; at each edge is a notch in the upper edge which engages with a downward projecting flange on the outer edge of the plate. Double-headed rails are used, and are supended in the jaws, as in the Denham-Olpherts ties.

PATNA-GYA RAILWAY.—This line is now operated as a part of the East Indian railway system. Cast-iron bowls were in use in 1877. (See State Railways and East Indian Railway).

RAJPUTANA-MALWA RAILWAY.—This line is leased by the Bombay, Baroda and Central India Railway Company and forms a part of its system. Wooden ties of deodar and creosoted pine were originally used, but as the latter perished very rapidly they were replaced with deodar. The Fazilka Branch (50 miles long) of the Rewari-Ferozepore section is laid with steel rails on Molesworth's and Denham-Olphert's iron ties. (See State Railways.)

BENGAL-NAGPUR RAILWAY.—This road is to be about 800 miles long, and at a meeting of the company in London in June, 1889, it was stated that 294½ miles were then open for traffic; track had been laid on 260 miles more, of which 45 miles were ready to be put in operation as soon as the rainy season was over. Some of the older sections of the line, built about 1880–1881, were of 1-meter gauge, but the Indian gauge of 5 feet 6 inches having been adopted, these lines are being converted to the broad gauge.

The type of track adopted consists of steel flange rails on steel cross-ties, except in those places where timber can be readily obtained from neighboring forests. In April, 1888, there were 180 miles laid with steel ties (See plate No. 25). These ties are of the type now adopted for the State railways (already described). They are 8 feet 9 inches long, bent to give the rails an inclinatien of 1 in 20, and have the ends curved down with a radius of 9 inches and flared out to a width of 13 inches. They weigh 120 pounds each or 122 pounds, with two keys. The rails are secured by clips stamped up out of the top table of the tie; for the meter-gauge sections two sets of clips are made, one set for each gauge, the object being to permit of converting the gauge of the line, while keeping the meter-gauge open for traffic. The rolled section from which the ties are made is of trough shape, 9 feet long, flat on top for a width of $5\frac{7}{8}$ inches, $11\frac{5}{8}$ inches wide at the bottom, $3\frac{13}{16}$ inches deep; the thickness is seven-thirty-seconds inch, with the middle part of the top table three-eighths inch thick for a width of $4\frac{1}{2}$ inches; the corners are bent to a curve of 1 inch radius. At the middle the cross-section is $4\frac{7}{8}$ inches deep, 8 inches wide at the bottom; the top is curved to a radius of $10\frac{1}{2}$ inches, and the corners to a radius of $1\frac{7}{8}$ inches; the distance between the centers of the corner curves is $3\frac{5}{8}$ inches, and the sides flare outward slightly towards the bottom. At the rail seats the top is flat, giving a width of $4\frac{1}{2}$ inches; the section at the inner rails (meter gauge) is $8\frac{1}{2}$ inches wide at the bottom and $4\frac{3}{8}$ inches deep; at the outer rails (broad gauge) it is 10 inches wide at the bottom and $4\frac{3}{8}$ inches deep. The clips are 3 inches long and the keys 8 inches and 6 inches long for the broad and narrow gauges respectively. The adjustment of the gauge is effected by driving one or both of the keys on the inside instead of the outside of the track. The ties are steeped while hot in linseed oil and tarred. They were manufactured by Bolckow, Vaughan & Co., of England, and cost $24.54 per ton, or about 4 rupees 8 annas ($1.48) each in India. The ties are spaced 3 feet center to center, 1,760 to the mile. They are laid in ballast of broken stone $1\frac{1}{2}$ inches size; this behaves well under the ties, does not crush, and is elastic and clean. It has also been proposed to lay some Denham-Olpherts cast-iron-plate ties as an experiment.

These steel ties were adopted on account of the low cost of steel and because timber was not procurable in sufficient quantity. Wooden ties last about five years; they soon split from the intense heat, and rot during the rainy season. The climate has no effect on the metal ties. Wooden ties are used to some extent, and the rails are secured to them by spikes five-eighths of an inch square in the shank and 5 inches long under the head, with a notch cut in the sides at a distance of $1\frac{3}{4}$ inches from the point. The meter-gauge line was laid with 40-pound rails on teak, sâl, and creosoted pine ties. One advantage of the steel ties is that the number of separate pieces is small and the fastenings are simple, which makes the track very easy to lay with rapidity and accuracy. It is said that rust is liable to form at the rail-seat, but the engineers have no anxiety on this account. The space between the clips being narrower than the flange of the rail, the rails have to be canted when being put in or taken out, and this causes a good deal of extra work when tie renewals are to be made. It is said by outside authorities that the ties are of too light section, the finished thickness being about three-sixteenths of an inch. The road being new, there has not yet been time to ascertain their durability or the expense of maintenance, but up to the date of the reports received (April and May, 1888), the general results have been satisfactory; not one tie had been damaged and the engineers were well satisfied with them. Mr. T. R. Wynne is chief engineer and Mr. P. T. Large is superintending engineer.

The rails for the meter-gauge weigh $41\frac{1}{4}$ pounds per yard. They are $3\frac{15}{32}$ inches high, with a head $1\frac{27}{32}$ inches wide (having inward flaring plane sides), and a flange $3\frac{7}{32}$ inches wide; the clear distance between the clips for these rails is $2\frac{7}{8}$ inches. The rails for the broad gauge weigh 75 pounds per yard; they are $4\frac{15}{16}$ inches high, with a head $2\frac{11}{32}$ inches wide (having inward flaring rounded sides), and a flange 4 inches wide; the clear distance between the clips for these rails is $3\frac{3}{4}$ inches. The joints are suspended and are spliced by angle splice-bars 26 inches long, with a very narrow horizontal flange; there are six bolts, the inner ones spaced 6 inches and the outer ones 4 inches, center to center. The ruling grade is 1 in 150 and the sharpest curve 1,000 feet radius. The engines are all of one class with six coupled wheels; total weight, without tender, 45 to 50 tons; weight on a pair of wheels, $11\frac{1}{2}$ to 12 tons. In addition to the passenger traffic there is a heavy traffic in grain; also in hides, salt, timber, and bamboos.

SOUTHERN MAHRATTA RAILWAY.—Steel cross-ties of the state railway type are now being substituted for the creosoted pine ties. In the report for the half year ending June 30, 1888, it was stated in regard to the renewals of ties that some part of the line was built as a famine relief work by the Government before the railway company came into existence, and the Government provided also some of the tract, which the company laid down. On the older state lines of meter-gauge half-round creosoted pine ties had been largely used, but they proved a failure and had to be renewed. The greater portion of this line, about 80 per cent., is laid with teak or steel ties, and it was hoped that the renewals would be less expensive than on other roads. About 10 per cent. of the ties in the line were then of creosoted pine. The number would be about 200,000, and 27,000 had been renewed during the half year.

Mysore section.—The track is laid with $41\frac{1}{4}$-pound rails, on teak and creosoted pine ties.

Bellary-Kistnah section.—Early in 1888 reports on the new type of steel ties (state railway type) were made by the district engineers to Mr. La Touche, the engineer-in-chief, who reported to the director-general of railways in September, 1888. The old pattern of tie, of somewhat similar form, but with gib and cotter fastenings, was objectionable on account of the number of small pieces—eight to each tie—while the metal was so thin as to be easily broken by derailed cars or split by driving the keys home. There was no adjustment for curves. The close spacing of the clips of the new ties was objected to. In stone or clean gravel ballast they do very well, but in soil banks the edges cut down into the material and a good deal of extra raising and packing was required. The increased thickness of the top table greatly increased the strength and efficiency of the tie. (See State Railways.)

INDIAN MIDLAND RAILWAY.—The older parts of this line are laid with double-headed rails, weighing 75 pounds per yard, on Denham-Olpherts cast-iron plate ties. The remainder of the main line and branches are laid with steel flange rails weighing 80 pounds per yard, on cast-iron bowl ties (See plate No. 23.) These bowls are an improvement upon those of the state railways. They are oval in plan, 25 inches long by 20 inches wide, and $2\frac{5}{16}$ inches deep under the rail. In the top there are two holes $2\frac{1}{2}$ inches in diameter, for tamping. The tie bar is of wrought iron 7 feet 7 inches long, 2 inches deep by one-half inch thick; it is secured to each bowl by a cotter on the outer side and a gib on the inner side of the track. There are eleven pairs of ties to a rail length of 30 feet; they are spaced 2 feet $9\frac{1}{4}$ inches center to center of tie bars, and 1 foot $1\frac{3}{4}$ inches at the joints. The spacing of the ties is slightly modified with a rail length of 29 feet $7\frac{1}{2}$ inches, but the three middle ties are spaced as above—2 feet $9\frac{1}{4}$ inches—for the reason that holes are drilled in the outside flange of the rail and at the tie on each side of the middle tie, for a pin five-eighths inch diameter and $1\frac{5}{8}$ inches long; these pins are to prevent the creeping of the rails. The rails are of flange section, resting on a piece of felt packing on the rail seat; the rail seat has an inclination of 1 in 24. The outer flange of the rail is held by a projecting lug, cast on the bowl. The inner flange is held by a cast-iron clamp 4 inches long, the upper part of which has a projection which bears on the rail flange, the lower part being dovetailed so that there is no vertical motion. This key is dropped into place, the lower part fitting into a pocket or recess in the bowl, and a wrought iron taper key $6\frac{1}{4}$ inches long is driven between it and the jaw of the chair; the split end of this key is then opened out to prevent the key from slacking back. The bowls weigh 92 pounds each and the rails 80 or 82 pounds per yard. The desirability of using the creosoted felt under the rails in a hot country like India, is an open question and practically the method has fallen into disuse. The adjustment of the gauge is effected by means of the tie bar fastenings; with both cotters on the outer side and both gibs on the inner side of the track, the gauge is 5 feet 6 inches; if the gib on one bowl is placed on the outer side of the track the gauge will be widened one-eighth inch; if both cotters are placed on the inside and both gibs on the outside, the gauge will be widened one-fourth inch. The ballast used is of stone broken very small, and there are about $15\frac{1}{2}$ cubic feet of ballast per foot run of tract. The rail joints are suspended, and are spliced with ordinary flat-fish plates and five bolts; the ends of the webs of the rails are notched to admit the middle bolt, which thus keeps the ends of adjacent rails at the same horizontal plane, and thus reduces the pounding of the joints by the wheels of trains. It has been reported to me that the track is one of the smoothest in the country; so smooth that on passing over the line the joints are scarcely perceptible, even before the bowls are finally tamped. Denham-Olpherts cast-iron plate ties were laid on the Cawnpore and Jhansi Railway, which is now a part of the Indian Midland system.

VILLUPURAM-DHARMAVARAM RAILWAY.—The state railways steel cross-tie has been tried on the Cuddapah-Nellore line, now a part of this system. Mr. Bull, superintendent, in a letter to the director-general of railways in February, 1888, stated that the ties are lighter than those of the Denham-Olpherts type, and the simplicity and small number of parts makes the track-laying very easy. The trough shape of the tie renders the track more difficult to align, but once in line it also prevents its moving. It is difficult to pack but may be considered self-packing; a hole might be punched at each end so that it can be seen if the tie is properly packed. Pebble or coarse sand ballast should be used. He considered it on the whole an excellent tie and superior to the Denham-Olpherts type.

DHOND-MANMAD RAILWAY.—The track of this line, which is operated by the Great Indian Peninsula Railway Company, consists of double-headed steel rails weighing 70 pounds per yard laid on ties of cast-iron bowls weighing 94 pounds each.

BHOPAL-ITARSI RAILWAY.—This line is also operated by the Great Indian Peninsula Railway Company. The rails are of steel weighing 62 pounds per yard, and the ties are partly of steel and partly of creosoted pine and other kinds of wood.

NORTHWESTERN RAILWAY.—This system includes the Sind, Punjab and Delhi, the Punjab Northern, the Indus Valley, the eastern section of the Sind-Sagar, and the southern section of the Sind-Pishin railways, on which different kinds of wooden and metal ties are used. These lines have all been amalgamated into one system under the name of the Northwestern Railway, with a total length of nearly 2,500 miles. Three types of metal track are used, viz, cast-iron bowls, Denham-Olpherts cast-iron plates, and the state railways steel cross-tie (See Plate No. 24). Mr. F. R. Upcott, the engineer-in-chief, has furnished me with a detailed statement, dated in July, 1889, in regard to this line, referring principally to the steel ties, as they are to be the future standard, the cast-iron bowls and plates becoming obsolete. The types of track include double-headed and bull-headed rails on wooden ties, flange rails on wooden ties, double-headed and bull-headed rails on cast-iron bowls. These are being gradually replaced by the 75-pound rails on steel ties.

There are about 600 miles laid with these steel ties; of this length 400 miles are in easy country, the remainder being on grades of 1 in 40 and 1 in 25, with curves of 800 feet radius and upwards. They were laid in 1886 and 1887 under the supervision of Mr. Upcott. The traffic is light; on the level plains the trains are hauled by engines weighing about 50 tons, and on the heavy grades by engines weighing 62 tons, with 14 tons on the driving axle. The ties are of the type adopted on the state railways, but are of two patterns, one of which has the ordinary form of clips, while the other has clips strengthened by a corrugation lengthwise of the tie, forming a rib and reducing any tendency to force open the clip or split the tie; it is not, however, thought to be an advantage. They are 8 feet 9 inches long, of rounded trough section, bent up at the rail seats to give an inward inclination to the rails, and having closed ends rounded and dished. The ties with corrugated clips are 4⅛ inches deep and 8½ inches wide at the middle, 3⅜ inches deep and 9½ inches wide at the rail seat, and 12 inches wide at the end. They are made from plates 1 foot 1½ inches wide, 9 feet long, one-fourth inch thick at the sides, and one-third inch thick for a width of 4½ inches at the middle, but the thickness is increased gradually. The other ties are 4⅝ inches deep and 7½ inches wide at the middle, with the top table 12 inches radius and top corners 1¼ inches radius; the width is 10 inches at the rail seats and 13 inches at the ends, which are closed by a vertical curve of 7 inches radius. The top table has an extra thickness for a width of 4½ inches. The sizes of the clips and keys are the same as on the state railways, and the adjustment of gauge is made in the same way as on those lines. In the track the ties are laid 3 feet apart, center to center. Their durability so far has been good. Some have been laid in very saline soil, which has stripped off the preservative coating, but the steel has not suffered much in the two years it has been in the track. Experiments are being made as to corrosion, etc. The ties are manufactured by the principal steel-making firms in England, and are dipped in Dr. Angus Smith's composition at the works. The cost is from $23.75 to $25 per ton. As regards expense for maintenance, for ordinary roads the average is 2½ men per mile of single track, costing 7 rupees ($2.33) per man per month; for frontier and hilly roads, 3 to 4 men per mile, costing $3.30 per man per month.

The rails are of steel flange section, weighing 75 pounds per yard; $4\frac{15}{16}$ inches high, $2\frac{11}{32}$ inches width of head, 4 inches wide over the flange. For 200 miles the ballast is of sand covered with 3 inches of broken stone or brick; at the rails it is 12 inches deep and covers the flanges of the rail; in the middle of the track it is 9 inches deep, leaving the top of the tie exposed; the side slopes are 2 to 1, and the width of the ballast at sub-grade is 15 feet. This method answers very well where the rain-fall is small and high winds do not prevail. Stone, either in a natural state or broken up by hand, is also used, and answers very well after the track has been laid for some months; at first a good deal of packing is required to get the ballast up into the hollow of the tie.

The steel ties were adopted for reasons of economy and progress, track with wooden ties not being satisfactory in India. The general results may be said to be satisfactory, but the element of durability has not yet been fully established. There is no trouble with maintenance except that more attention has to be given to keeping the middle of the ties free. In laying for the first time the rails have to be canted to get them into the seat between the lug, and it is difficult to take out any single tie without unduly pinching back the lip of the lug. The key never shifts after driving and opening out the split end. As to breakages, Mr. Upcott says he has only seen half a dozen broken ties out of half a million, but they get crumpled up under an engine derailment, especially if not well backed up. A steel die is used to bring these distorted ties into shape. The wooden ties cost about 3 rupees ($1) each; they are mostly of deodar or *pinus excelsior*, growing in the Himalaya; it lasts from ten to fifteen years, if properly managed. The steel ties cost about 6 rupees ($2) at a mean distance from the port, and they are better able to stand the climate than the wood. Mr. Upcott is satisfied that the only point to be urged against the ties is possibility of fast corrosion. His three years of experience with them leads him to think that the mild steel of which they are made will not corrode so fast as the wrought-iron and cast-iron now corrodes on the worst places on the line, where the soil is saturated with chlorate of sodium. In a report to the director-general of railways in March, 1888, Mr. Upcott stated that the new type of steel ties (state railway pattern) laid in sand ballast on the Sind-Sagar line, answered very well; they were easy to pack, and the keys held quite tight, even when not split at the ends. Only one or two cases of hogging had been reported, which were due to the tie riding on hard material at the middle. The rusting was slight, and no breakages had occurred. The rails did not creep, and this was attributed to the absolute fixture of the rail on the tie and to the latter being anchored in the ground by its sides.

The cast-iron bowls used are of oval form, 25 inches long by 21 inches wide, the greater length being parallel with the track; the thickness was about seven-sixteenths to one-half inch. The rails are of double-headed section resting on two wooden cushions, and fastened between the jaws of the chair by a wooden key. The tie-bars are 2½ inches deep by five-eighths inch thick, passing through both bowls and secured by a gib on the inner side and a cotter on the outer side of each bowl. The ballast is sand covered with 3 inches of broken brick or stone; the bowls are imbedded nearly up to the chairs. The depth of ballast is 14 inches under the rails, decreasing to 12 inches at the top of the side slopes of 1½ to 1, and 8 inches between the rails. The width of ballast bed over the toe of the slopes is 13 feet 6 inches.

The Denham-Olpherts cast-iron plate ties are of the type adapted for double-headed rails, the rails being suspended by the head in the jaws which form the chair. The plates are 2 feet 10 inches long and 12 inches wide, the greater length being transverse to the track; a rib runs across the middle of the plate on the bottom side, thus giving a hold in the ballast to resist lateral motion of the track. The rail chairs are $7\frac{3}{16}$ inches long. The tie-bars are 2 inches by one-half inch, 7 feet long. They are secured by a gib on the outer side of the track, and a large cotter on the inner side, this cotter passing through the webs which run from the chair to the edges of the plate, and holding the loose jaw of the chair in its place. The webs are transverse to the track, 3 inches high at the rail-seat and tapering down to the edges of the plate.

Mr. Croudace, superintendent of way and works of the Sind section, wrote me in May, 1889, that he thought the Denham-Olpherts plate-tie, with the cast-iron jaws supporting the upper head of the rail, to be the most satisfactory, in spite of its having a tie-bar passing through a flat cast-iron table. The pressed steel ties he considered are difficult to pack, but have the advantage in simplicity and a minimum number of parts; there is, however, a leverage of the rail to break the clips.

The report of the director-general of railways for the year ending March 31, 1888, makes mention of about 630½ miles of metal track on the Punjab section, out of a total of 1,489¾ miles; this includes 259 miles of steel ties, about 242 miles of oval bowls, 85 miles of round bowls, 39½ of bowls (not described), and 5 miles of old bowls (on a branch). On the Sind section the same report mentions about 400 miles laid with Denham-Olpherts plate-ties; the length of this section is 895 miles.

The Sind, Punjab and Delhi Railway, now a part of the Northwestern Railway, is still laid with cast-iron bowls for a considerable distance, but it is said that they are not now considered so favorably as formerly in that part of the country. Bowls were used on this line more than twenty-years ago. In 1877 it was stated by Mr. Ernest Benedict, in his paper on "Metal sleepers for railways," read before the Society of Engineers and Ship-builders, at Glasgow, Scotland, that the general opinion of the engineers, based upon the experience of ten years, was decidedly favorable to iron bowls in preference to wooden ties, though some thought that they should only be used in certain kinds of ballast. The former cost about 86¼ rupees ($28.75) per ton, and the latter 4 rupees ($1.33) each. Owing to the use of sand and earth ballast (which when boxed with bricks broken fine came to 2,950 rupees ($983.33) a mile, as against 12,040 rupees ($4,013.33) for the ballast of broken brick throughout, used with wooden sleepers), the cost of the iron road compares favorably with the wooden one, being 37,000 rupees ($12,334) a mile for the wood and 34,000 rupees ($11,334) for the iron.

Sind-Pishin Railway.—On this line the steel ties of the state pattern are used. Mr. F. L. O'Callaghan, engineer in chief of the northern section, made a report on these ties to the director-general of railways in April, 1888. He gave the following comparison of the weights and numbers of parts of different ties:

	Weight.	Parts.
	Pounds.	*No.*
(*a*) Steel tie	120	3
(*b*) Deodar	143	5
(*c*) Teak	160	5
(*d*) Denham-Olpherts	229	9
(*e*) Bowl	180	9

a, tie and 2 keys; *b* and *c*, tie and 4 spikes; *d*, 2 cast-iron plates, 2 cast-iron jaws, 1 wrought-iron tie-bar, 2 wrought-iron gibs, and 2 wrought-iron cotters; *e*, 2 bowls, 1 tie-bar, 2 gibs, 2 cotters, 2 keys.

The track, he stated, is easily and rapidly laid, but somewhat difficult to pack up in the first instance. The practice was to put the ballast in two parallel heaps about 6 feet apart center to center, and about 18 inches high; the ties spanned these two stacks and were forced down into them by the first passage of an engine; the space under the rail was thus solidly filled and the space between the stacks of ballast was then filled in with sand, as any hard material under the middle of the tie is liable to cripple it. The narrow space between the lugs was complained of, but it was stated that if made wide enough to admit the rail flange horizontally, four keys would be required on curves instead of two; and "the remedy, by introducing special parts, seems worse than the disease." The turned down ends of the ties hold the ballast so firmly that very little is required beyond the ends. Some cases were reported in which the lugs were cracked off, and an increase in the thickness of the top table, by adding metal to its under side, was recommended. As to the strength of the ties, it was stated that under ordinary circumstances they are as strong as timber; a heavy derailment distorts them, but under similar circumstances wooden ties are generally smashed up, and any kind of cast-iron ties so broken as to be useless, the tie-bars only being repairable. Other reports, made about the same time, suggested the use of a loose-bolted clip on one side of each rail, and also that the lugs should be made stronger. A number of objections were urged against the old form of steel tie (state railways pattern, 1885).

Oudh and Rohilkund Railway.—This road is laid with metal track throughout. In March, 1888, there were 432 miles of cast-iron oval bowl-ties, 75 miles of wrought iron saddle-ties, and 182 miles of MacLellan and Smith's patent Bessemer steel corrugated bowl-ties. The Cawnpore branch, 45½ miles long, of which 42 miles were built in 1867, was originally laid with 36-pound rails, on corrugated iron bearing plates, but has been relaid with the cast-iron oval bowl-ties and the 60-pound flange-rails used on other parts of the line. The corrugated or embossed steel bowl-tie made by P. & W. MacLellan, of Glasgow, is said to be the standard type of tie now for this line, and it was of these that Sir A. M. Rendel, consulting engineer for state railways, wrote in 1888 that they had lasted sixteen years without injury. These bowls are also in use on the Calcutta Port Railway. At the beginning of 1875, as stated by Mr. Ernest Benedict in his paper on "Metal sleepers for railways" (already referred to), 1877, there were 444 miles laid with oval cast-iron bowls, having recessed pocket for wooden cushions; 60-pound flange-rails were used, secured by iron keys; the principal defect was in the jaw which held the key, 75 per cent. of the breakages occurring at this point. A bowl and fastening, exclusive of tie-bar, weighed 87¼ pounds. In the discussion of this paper Mr. J. E. Wilson stated that the wrought iron saddle-tie had been adopted on this road in 1869, and notwithstanding its weak form it had given such satisfaction that its use was continued, 25 miles being laid in 1876. After a series of tests the use of iron for ties had been abandoned and embossed steel ties adopted; these were only three-sixteenths inch thick, as it had been found that there was no danger of corrosion. A pair of these steel bowls would weigh about 90 pounds, while a pair of cast-iron bowls would weigh not much less than 224 pounds. The steel bowls could be struck out of a steel plate at one blow.

JAMMU AND KASHMIR RAILWAY.—In the report for the year ending March 31, 1888, of the director-general of railways, it was stated that the track was to be of the most improved type in use on the North-western Railway (presumably 75-pound flange-rails on steel cross-ties of the state railways type.)

EASTERN BENGAL RAILWAY.—The report of the director-general of railways, for the year ending March 31, 1888, mentioned 34 miles laid with cast-iron bowls, 20 miles with Denham-Olpherts cast-iron plate-ties, 10 miles with Denham's plate-ties, and one-fourth mile with Greaves' cast-iron bowls; also Vautherin wrought-iron and De Bergue cast-iron ties (length of track not stated) on the northern section (see State Railways); and Denham-Olpherts plate-ties on the Assam-Behar section. On the Goalundo extension, opened about 1871, 8 miles of the main line were laid with spheroidal cast-iron bowls, packed with the ordinary sand of the country. Mr. Ernest Benedict, in his paper on "Metal sleepers for railways" (1877), already referred to, stated that they were laid in sandy earth packing and the grass allowed to grow over it, except within 6 inches of the rails, thus protecting the sand from being washed away by the rain or blown away by the wind. This was expected to save the cost of burning clay or brick for ballast, about $7,500 per mile, and to effect a great economy in maintenance. These views were found in practice to be correct. There were eight pairs of bowls to a rail length of 20 feet, as compared with seven wooden ties; they were first laid on brushwood and packed with sand, but later the ordinary sandy loam only was used, packed from below by wooden beaters and then tamped through the holes on top. The bowls were 22½ inches in diameter, nine-sixteenth inch to 1 inch thick; the tie-bars were 2½ inches by ½-inch section, 7 feet 4½ inches long, and weighing about 31½ pounds; they were secured by cotters on the outside and gibs on the inside of the track. The rails were of double-headed section, weighing 74 pounds per yard. Particular attention was paid to the drainage; besides the ordinary trench between the rails, four cross drains were cut to each pair of rails, two to the right and two to the left between alternate ties; the embankment itself was rounded off and there was not a square foot of level surface upon its top. There were seven trains each way per day, with four-wheel freight cars weighing 16 tons (10 tons of freight) and heavy engines with four coupled wheels. Mr. Benedict gives the following figures in regard to renewals:

> In the half year ending June 30, 1876, 14,130 wooden ties were renewed, or at the rate of nearly 10 per cent. per annum of the main line ties, bringing the total renewals, which have been mostly on the main line, to 34.33 per cent. of the whole number of ties, and leaving 40 per cent. of all the ties in the line fifteen and one-half years old; but these are mostly in sidings. Taking, then, that nearly all the renewals

have been on the main line, the yearly average so far (1877) has been 3.44 per cent.; but it may also be taken as certain that another 33 per cent. of the total number of wooden ties will have to be removed from the main line during the next two years (to 1879). This would give a yearly average of 6 per cent., or a life of sixteen and one-half years to the old ties now in the track, of which two years passed before the line was open for traffic. Against this we have 364 or 1.25 per cent. of bowls renewed in the half year, making a total of 6.17 per cent., all on the main line, and giving a yearly average of a little over 1 per cent., or a life of eighty-nine years to the bowls.

TIRHOOT RAILWAY.—In 1878, Sir Guilford L. Molesworth designed some cast-iron bowls for this line (See State Railways). There are now in use the Denham-Olpherts and Denham's cast-iron plate-ties; also sâl and deodar wood ties.

JORHAT RAILWAY.—Fowler's patent portable track, with 14-pound steel flange-rails on corrugated steel cross-ties, is laid for 3 miles; the rest of the line is laid with 18-pound rails on wooden ties.

CHERRA-COMPANYGANJ RAILWAY.—On this line 7½ miles are laid with 25 pound steel flange-rails on Fowler's patent steel ties for light railways. The ties are flat, with a middle corrugation forming a deep groove along the upper surface of the tie. The outer flange of the rail is held by a clip secured to the tie by two bolts; the inner flange is held by the hooked end of a bolt which lies in the groove under the rail, with a nut screwed up against the end of the tie. The ties are 45 inches long, and there are eight to a rail length of 21 feet. This part of the line is worked by locomotives. On the mountain inclines, worked by steel wire ropes, wooden ties are used.

BURMAH RAILWAYS.—Until very recent years the ties used in Burmah were almost exclusively of iron-wood, or teak. The former is an excellent timber, impervious to white ants, and little troubled with dry-rot. The teak is softer, and lasts eight or ten years. Steel ties, however, have been experimented with, and are now being introduced, as they economize in the expense of spikes, and are claimed to last forty or fifty years. Recent low prices have greatly aided the introduction of steel rails and steel ties.

MADRAS RAILWAY.—The track of this road is laid almost entirely with cast-iron bowls, carrying rails weighing 65 to 84 pounds per yard. The southwest section was originally laid with ties of indigenous woods, but as early as 1853 the then chief engineer, Mr. G. B. Bruce, suggested that an experiment should be made by using stone blocks 2 feet by 2 feet by 1 foot. The Government acceded to the proposal and sanctioned the purchase of 60,000 stone blocks. Apparently, however, only about 800 yards were laid in this way, and, as the experiment proved to be unsatisfactory, the blocks were all removed in 1857. Jungle-wood ties were found to be very short-lived, and in 1861 it was decided to replace them by Greaves's patent cast-iron bowls. This alteration has proved to be economical and satisfactory. The northwest section, 308 miles long, and the Bangalore Branch, 87 miles long, are laid with iron ties. In 1877 it was stated by Mr. Benedict, in his paper on "Metal Sleepers for Railways," already referred to, that nearly the entire line was laid with the bowls, except about 70 miles laid in laterite rock-ballast, and in that part trenches were being made in the ballast to be filled with sand, so that the bowls could be put there also. When the bowls were carefully packed they made a smooth track, easy to ride over, and safe for high speeds. At one time tie-bars were only used to every alternate pair of bowls, but now they are used for every pair. The cost of maintenance, as compared with jungle-wood ties, was found in five years to be as 3 to 1 in favor of the bowls. Creosoted pine ties have been tried, but are not preferred to the iron. About 1886, there was a period in which this form of tie, however, fell into disfavor, but it has survived up to the present time.

From a paper, with illustrations, by Mr. E. W. Stoney, chief engineer, on "The Creep of Rails on Double Lines of Railway," published in The Indian Engineer, Calcutta, October 29, 1887, the bowls were of the Greaves pattern (See State Railways); they were about 24 inches in diameter, arranged in pairs, and connected by transverse tie-rods; the ties were spaced 2 feet 6 inches apart, center to center of tie-rods, at the rail-joints, and 3 feet 6 inches apart intermediate. The distance between the near rails of the two tracks is 6 feet. The rails are of double-headed section, weighing 75 pounds per yard; they are 20 feet long, connected by splice bars and four bolts, the joints being even and suspended. The ballast is of sand. The taper of the keys and the jaws of the bowls was in the direction of the traffic for the outside rails of each track, and in the opposite direction for the inside rails. The creeping of the track in the direction of the traffic, therefore, tended to tighten the keys of the outside rails and to loosen those of the inside rails; consequently, the creeping of the inner rails was much greater than that of the outer rails. In regard to this creeping, which is a matter of importance to railway engineers, Mr. Stoney states that it is in the direction of the traffic; the joints are sometimes drawn out as much as 5 inches, when the fish-plate came against the jaws of the bowl; but even then the force was sufficient to pull the bowl through the ballast, sometimes bending the tie-bars, shearing or breaking three-fourths inch splice bolts, and breaking the jaws of chairs which were immovably fixed on girder bridges.

SOUTH INDIAN RAILWAY.—This line was formerly the Great Southern of India Railway. It was commenced in 1859, and was built to the Indian gauge of 5 feet 6 inches, but during the years from 1875 to 1879 it was converted to meter gauge. Cast-iron bowls were made for this road in 1877 (as described under State Railways). In that year the road had 86 miles laid with these ties in sand ballast; they were laid with seven pairs to a rail length of 21 feet. At first tie-bars were only used at every alternate pair of bowls, but now at every pair. Each bowl had a teak cushion on which the rail rested. On the broad-gauge line, about half was laid with iron and half with wooden ties. As the latter decayed they were replaced with iron. The track was laid with 40-pound rails and light ties, but it is being rapidly relaid with 50 pound rails and heavier ties. In October, 1889, the consulting engineer, Sir Douglas Fox, informed me that there were about 140 miles laid with cast-iron bowls, and extensions aggregating 300 miles were being laid with steel ties of the State Railways pattern for meter-gauge, large numbers of which were sent to India. In his opinion, the cast-iron tie is by far the best under most circumstances. The grades and curves of the road are easy. The engines have a weight of about 3½ tons on the driving wheels, and they haul the trains at a speed of about 25 miles per hour.

The bowls are 20 inches long at the bottom, at right angles to the rail. The thickness of the metal averages eleven-thirty-seconds inch, and the weight is 70 pounds each. The height from the bottom of the bowl to the top of the jaws, forming the rail-chair, is 7⅜ inches, and 7⅝ inches for the inner and outer jaws respectively. The tie-bar is of wrought-iron, 1⅝ by three-eights inch section, 5 feet 6¼ inches long, and weighs 11 pounds. It is placed on edge, and passes through the bowls, being secured on the outer side of each bowl by a split cotter, and on the inner side by a gib. The cotters weigh 43½ pounds per hundred, and the gibs 17 pounds per hundred. The rails are of steel, of bull-headed section, weighing 50 pounds per yard. The lower table rests on a wooden packing-piece, or cushion, and a compressed oak key, or wedge, is driven between the web of the rail and the outer jaw of the chair, the jaw being corrugated so as to bite into and hold the key. The rails have an inward inclination of 1 in 20. The ballast is of a stone called laterite. The cost of construction of the road is said to have been about $33,500 per mile.

A special feature of some of the steel ties used (not the state railways pattern), was that the clips were not stamped out of the metal of the tie, but two wrought-iron plates with jaws were secured to each tie by four rivets, each rail resting on a plate. They were laid in April, 1885, to replace creosoted pine ties, and in October, 1888, Mr. David Logan, chief engineer, reported that some had been found cracked round the plates, the weight of the traffic appearing to have a tendency to punch the plates through the tie. The cracked ties weighed about 62 to 64 pounds each, while the average weight of ties of this class was about 70½ pounds. The rails were of flange section, weighing 40 pounds per yard, and were secured by wooden keys in the same way as a double-headed rail in a chair.

GREAT INDIAN PENINSULA RAILWAY.—On this line, cast-iron bowls are extensively used. They have been adopted for the standard track of the road as a form of bowl which gives good satisfaction, arrived at by gradual improvement. They are of oval shape, and are spaced 2 feet 9 inches apart, center to center. They are being used not only for maintenance and renewals, but also on the double tracking of the lines. As laid in 1877, there were eight pairs of bowls to a rail length of 24 feet. The rails were of iron, and weighed 68 pounds per yard. The rails now used are of steel, and weigh 69, 82, and 86 pounds per yard. At a meeting of the company in June, 1889, the president, in presenting the report for the half year ending December 31, 1888, made the following remarks in regard to the ties used:

> When the railway was first worked wooden sleepers were very largely used. We found in very early days that it would be advantageous to introduce iron sleepers in substitution for wood. It was done in some degree tentatively, but with some rapidity after a little while. In 1872, just after the railway had been completed throughout, our road consisted of 1,110,000 iron sleepers and 1,638,000 wooden sleepers. Many of the wooden sleepers have been replaced, and we have now 2,190,000 iron sleepers as compared with 977,000 of wood; and the advantage of this is that while one represents the renewal of iron sleepers per hundred, it takes 5.09 of teak wood sleepers and pine sleepers to do as advantageously as the iron does, and the effect is that you get done with 1 per cent. that which takes more than 5 per cent. in the case of the teak sleepers, which are the next durable we have.

BOMBAY, BARODA AND CENTRAL INDIA RAILWAY.—In September, 1889, Mr. J. M. Sleater, the chief engineer, forwarded me a statement in regard to this road. There were then 77.48 miles laid with the cast-iron bowls; they were laid at different dates, under the supervision of the late Mr. A. F. W. Forde and the late Mr. F. Matthews, who were successively chief engineers of the road. The steepest grade is 1 in 100; ruling grade, 1 in 500; sharpest curve, 1,500 feet radius. There is a heavy traffic, with freight trains of fifty cars. The total weight of engine and tender is about 62 tons, with 14 tons on the driving wheels. The bowls are oval in plan, about 21 inches by 26 inches, the major axis being parallel with the rail; the depth of the bowl (inside) is about 5 inches, and the total depth from the top of the jaws which form the rail chair to the bottom of the bowl is about 9½ inches. The thickness varies from about one-half inch to three-fourths inch. At the middle, between the jaws, the top is flat for a width of 6 inches; on this the rail does not bear, resting on two wooden cushions about 5½ inches long, 2½ inches wide, and 1 inch thick, in sockets of the casting, one on each side of the flat portion. There are two tamping holes 2¾ inches in diameter in the top of the bowl. They weigh 87 pounds each and cost 53 rupees 1 anna 8 pice ($17.25) per ton, delivered in Bombay; ten years ago the price was 64 rupees 2 annas 8 pice ($21.15) per ton. The tie-bars are 7 feet 7¼ inches long, 2 by ½ inch section, placed on edge; they pass through the bowls and are secured by a cotter on the outer side and a gib on the inner side of each bowl. The ties are spaced about 3 feet 5 inches apart, center to center of tie-bars. The rails are of double-headed section, of steel, weighing 69 pounds per yard; they are secured in the chairs by wooden keys or wedges. The rail joints are suspended and are spliced by deep splice bars, the lower part curved to clear the lower head of the rail. The ballast is of stone and gravel, but must not be more than 1 inch in size. The width of the ballast bed is 14 feet at the bottom, or at subgrade; 11 feet on top, with side slopes of 1 to 1; the top surface is flat, and is level with the under side of the rail heads. The width of embankments at subgrade is 18 feet. The ballast behaves fairly well under the ties. The reason for adopting metal ties was their supposed cheapness, and the general results have been fairly satisfactory; there is no trouble with the rail attachments, nor with maintenance; breakages, however, occur where the stone ballast is larger than 1 inch in size. Mr. Sleater considers the track not as good as that on wooden ties. The wooden ties used are of creosoted pine, cost 2 rupees 8 annas (80 cents) apiece, and have a life of about eight years. The following table shows the quantities and weights of the metal track per mile:

Material and weight, metal track.

Material.	Actual requirements.		Allowance for waste.	Weight per mile.
	Unit weight.	Number.		
			Pr. ct.	*Tons.*
Rails (30 feet long) ... pounds..	690	352	....	108.42
Bowls .. ... do....	87	3,168	2	125.50
Tie-bars ... do....	26	1,584	....	18.39
Cotters ... ounces..	10½	3,168	5	.97
Gibs ... do....	3½	3,168	5	.32
Fish-plates ... pounds..	10	704	5	3.30
Bolts and nuts ... do....	1½	1,408	5	.99
Total ...	....	....	....	257.89
Oak cushions ... ounces..	10	6,336	5	1.85
Wood keys ... pounds..	1	3,168	5	1.48

In his paper on "Metal Sleepers for Railways" (1877), already referred to, Mr. Ernest Benedict stated that on this line some thought that bowls were superior to wood wherever coarse sand or tolerably firm gravel was procurable, while others said that they should only be used where durable timber can not be obtained at a moderate cost. There were six pairs of oval bowls or seven wooden ties to a rail-length of 24 feet, giving about the same bearing surface, and, taking the cushions into account, about the same distance between the points of support. This very nearly equalized the original cost of the tracks, and it was found that the track on metal ties could be kept in order at about the same cost as that on the ordinary wooden ties. With broken stone, coarse shingle, or any ballast that cakes or hardens, the bowls were liable to be broken. In this respect circular bowls, ribbed, were found stronger than oval bowls. On the Nagpoor district there were many breakages, through allowing the track to run "hard," while in other districts, in sand ballast, the breakages did not exceed 2 per cent. per annum.

TARAKESHWAR RAILWAY.—This line is operated as a part of the East Indian Railway system, and is laid with Denham-Olpherts cast-iron plate ties of the latest type. (See East Indian Railway.)

DELHI, UMBALLA AND KALKA RAILWAY.—This is a new line now under construction, on which the Denham-Olpherts cast-iron plates are to be used, but up to June, 1889, no track had been laid. The rails will be of steel, double-headed section, weighing 75 pounds per yard. The ballast will be partly of brick and partly of stone, and the general type of track throughout will be in accordance with the standards of the East Indian Railway.

The southern division of 130 miles is over easy country, with a ruling grade of 1 in 300, while the northern division has a ruling grade of 1 in 40. The minimum radius of curves of the two divisions is one-half mile and one-fourth mile, respectively. Mr. R. A. Way is chief engineer and Mr. William Duff Bruce is consulting engineer. The cost is estimated at $32,500 per mile, exclusive of rolling stock. The cost of the East Indian Railway, including equipment, is given as about $110,000 per mile, and that of the Scinde, Punjab and Delhi Railway as about $80,000 per mile. The State will provide all rolling stock and will operate the line for 50 per cent. of the gross receipts. It will be worked by the East Indian Railway Company under a contract with the State.

THATON-DUYINZAIK RAILWAY.—The track of this road consists of steel flange rails on steel and wooden ties.

H. H. THE NIZAM'S RAILWAY.—Some cast-iron bowls of a type used on the state railways were in use on this road in 1877. At the end of March, 1888, 109¾ miles were laid with 66¼-pound steel rails on steel cross-ties of the state railways pattern, 87 miles with 68-pound rails on cast-iron bowls purchased from the South Indian Railway, 6 miles with 66¼-pound flange rails on Bessemer-steel ties, and the remainder with 60-pound flange rails on creosoted pine and jungle-wood ties. Mr. W. A. Lyle, chief inspector of maintenance, who has had nearly thirty years' experience with metal and wooden ties, wrote me in September, 1889, stating that, in his opinion, cast-iron ties were not reliable; wooden ties, he thought, cost too much to preserve, and even when preserved they were not reliable, as the gauge spreads under the lateral pressure of the wheels of trains, and the ties split and rot. In August, 1889, Mr. Lyle made a report to Sir A. M. Rendel, the consulting engineer, upon the State Railways type of steel tie, of which he had six years' experience, three years having been with the new pattern. He found this latter pattern superior to anything else he had ever tried, for the following reasons:

(1) It is easily handled and laid in the track.

(2) It holds well in line and surface.

(3) The gauge can be easily and uniformly adjusted on curves.

(4) The lugs are not too rigid, and the key is kept in place when once properly driven.

(5) The maintenance is easy when the track has become consolidated.

(6) If damaged by a derailment the tie can be repaired and made serviceable at a small cost.

He had not found the preservative coating to come off or the ties to rust except in a few rare cases, due to the use of bad ballast, impregnated with saltpeter, etc. Sand ballast he considered best, while broken stone he thought scratched the preservative coating and consolidated to too hard a bed, like macadam. To lessen the labor of packing and tamping he suggested the making of a packing hole 1¾ inches in diameter at each end of the top of the tie, the holes to be so punched as to leave a rib or burr around them. The cost would be small, and he estimated that he could carry on the maintenance with five men less for every 4 miles of line. He thought the ballast should be only level with the tops of the ties, not covering them.

In February, 1889, Mr. W. C. Furnivall, chief engineer, reported to the director-general of railways that his experience with the improved pattern of the State Railways steel ties was very favorable to their use. They can be easily and quickly laid, are preferable to timber in diversions on rough temporary roads, except only where stone and rock occur, and then only a sand packing must be employed. A line laid with these "pea-pod" ties is cheaply maintained; the ties keep their position well, and do not oxidize where the ballast is good. The slight friction caused by the passage of trains pressing the sand in stone ballast against the under side of the tie suffices to brush off any particles of oxidation which might otherwise exist. In cases of derailment he had found the ties easy to repair.

KHAMGAON RAILWAY.—The track of this line is laid with 60-pound flange rails on oval bowls. The road is operated by the Great Indian Peninsula Railway Company.

AMRAOTI RAILWAY.—This line is laid with 68-pound rails on iron ties. It is operated by the Great Indian Peninsula Railway Company.

H. H. THE GAEKWAR'S RAILWAY.—The Viramgam-Mehsana-Vadnagar Railway is laid with 41¼-pound steel rails on steel cross-ties. The line is owned by the Gaekwar of Baroda, and is operated by the Bombay, Baroda and Central India Railway Company. The other line, known as the Gaekwar's Railway, is laid with wooden ties.

BHAVNAGAR, GONDAL, JUNAGARH AND PORBANDAR RAILWAY.—The extension to Porbandar will be laid with 41¼-pound steel flange rails on steel cross-ties; this line will be 69 miles long. Of the 259¾ miles in operation, 193¼ miles are laid with similar rails on half-round pine ties, and 66½ miles with similar rails on jungle-wood ties from a local forest.

MORVI RAILWAY.—Part of this line runs along a highway. The track is laid with about 90 miles of 19-pound steel rails on Kerr and Stuart's patent steel ties, which are similar to the state railways type. (See Kerr and Stuart, England.)

JODHPORE RAILWAY.—The Pachpadra extension, 59¾ miles long, is laid with 36-pound rails on steel cross-ties. The main line is laid with similar rails, 19 miles on creosoted pine ties, and 45 miles on jungle-wood ties.

Calcutta Port Railway.—This is a line of 5 feet 6 inches gauge, owned by the port commissioners. The following report was kindly prepared for me by Mr. E. Desbruslais, assistant engineer, at the instance of the commissioners:

The line is in three sections: No. 1, from Chanpal Ghat, Calcutta, to the government gun foundry, Ghat, 4085 miles, laid with three tracks; No. 2, from Chanpal Ghat to Kidderpore docks, including the dock lines, 7.25 miles; No. 3, from the Kidderpore Docks to brick fields at Akra, 3.50 miles. Sections No. 1 and No. 2 are laid with steel bowls; No. 3 is only a temporary line. On section No. 2 the curves are very slight and the lines run generally level, except on each side of the level crossing at the approach road to the Hooghly floating bridge, where the grades are 1 per cent. for 600 feet. On No. 2 the sharpest curve is of 1,000 feet radius, and the line is nearly level. No. 1 was laid in 1875 with iron rails, which were replaced in 1885 with steel rails 30 feet long. No. 2 was laid in 1885–1886. Mr. William Duff Bruce was the engineer to the port commissioners when these works were carried out. No. 1 was intended to do away with as much as possible of the cart traffic on the Strand road and at the jetties; there is quite a heavy freight traffic. No. 2 is principally for conveying materials for the construction of the docks. The engines are tank engines, with four wheels, all coupled; wheel base, 6 feet; they were built by Dübs & Co., of Glasgow, and weigh 20 tons empty or 23 tons with tanks and bunkers full, giving 11½ tons on each pair of wheels. Each tie consists of two of MacLellan's patent steel embossed bowls, connected by a tie-bar; the bowls are of rectangular form, with all sides fluted; they weigh 33 pounds each (See plate No. 25). They are spaced 3 feet apart, center to center, and the rails are laid with suspended joints. The cost was £14 ($70) per ton delivered, and the average cost of maintenance (labor only) on section No. 1 is 26 rupees ($8.22) per mile of single track. The rails are of flange section and rest directly on the bowls, to which they are fastened by two bolted clips on the outer side and one clip on the inside; the outer bolts are seven-eighths inch in diameter and the inner bolts 1 inch in diameter. At curves a larger number of tie-bars is put in and the gauge is left one-half inch slack. The tie-bars are of angle-iron with adjustable clips and bolts at each end; they are spaced 6 feet apart, center to center. Ordinary freight cars are used, but the speed does not exceed 6 miles per hour. The materials appear to be wearing satisfactorily, but there has not been time enough to judge of their durability. Section No. 1 is ballasted with cinders, which are easily procurable and answer remarkably well for packing the bowls; the cinders are walled in by the curbstone of the road, the rails being level with the top of the curb; all rain-water drains through the cinders and is carried away in the roadside surface drain, so that the road-bed is well drained. Section No. 2 is ballasted with old bricks, broken to pass in any direction through a 2-inch ring; being rather soft they answer very well, but hard burnt brick would not be suitable. The cinders do not cake or harden into a mass under the bowls, but the brick ballast seems to be doing this. The suspended rail-joints on section No. 1 being very springy, Mr. Desbruslais designed a joint tie, which has been laid throughout this section with satisfactory results. The joints on section No. 2 are suspended. The general results of this track have been satisfactory so far, and there is no trouble with maintenance or with the rail attachments. When once the clips are fastened and the bolts tightened up they do not require any further looking after, as they get jammed up in a few weeks, and a difficulty is experienced if the bolts are required to be unscrewed. The fish-plate bolts, however, constantly require tightening. There is no trouble from breakages on the main line; it is only at switches and frogs that engines or cars get derailed, and, as the speed is slow, little damage is done. The switches and frogs are laid on wooden ties, with the ordinary cast-iron chairs; some of the chairs get broken and occasionally a switch rail and coupling-rod bent. The cost of the track laid complete, including the cinder ballast, is about 18 rupees ($6) per yard. The speed being only 6 miles per hour, the results that may be obtained on this line can not be assumed as similar to those that will be obtained from the use of this description of track on lines where high speeds are attained.

The rails are of steel, of flange section, and weigh 60 pounds per yard; they are 4¼ inches high, 4 inches wide over the flange, with a head 2¼ inches wide, having top corners of one-half inch radius. The bowls are about 30 inches long, 18 inches wide, and 4½ inches deep; the greater length is in the direction of the track. The rail joints are even and come between the bowls. The joint support designed by Mr. Desbruslais consists of a cast-iron plate and chair under each joint, without tie-bars. (See plate No. 25.) The plate is 24 inches by 12 inches, the greater length being transverse to the track. The bottom is flat, but at the middle of the upper surface is a support 6 inches high, forming the rail-seat. From each side of this two webs run to the edge of the plate. The splice-plates are double angle-bars, having a vertical web below the horizontal flange; on the inner edge of the bottom of this lower web is a rib, so that when brought together by the splice-bolts these ribs fit under the projecting top of the rail-seat and thus prevent vertical motion of the rails at the joint. The splice plates are 18 inches long, with four bolts. The tie-bars are of angle-iron, 2¼ by 2¼ by ¼ inch; they are placed between the pairs of bowls and connect the rails instead of the bowls, the latter being left quite independent of each other. At each end of the bar are two lugs, one fixed at the extremity of the bar, the other loose; the tops of these lugs are bent over to hold the rail-flange; when the rails are in place the lugs are held together by a horizontal bolt passing under the flange. In the middle of and between the tracks the ballast is level with the top of the rails, sloped down at the rails to the under side of the head. The space between the rails of adjacent tracks is 7 feet.

MISCELLANEOUS LINES.—The following railways are laid with wooden ties:

Dildarnagar-Ghazipur; 65-pound steel rails, on bearing plates and creosoted pine ties.

Bengal Central; 62-pound flange rails, on creosoted pine ties.

Wardha Coal; creosoted pine, teak, and sâl ties.

Toungoo-Mandalay (Burmah); flange rails, on teak and pyingado ties.

Bareilly-Pilibhit; 4¼ pound flange-rails, on deodar and sâl ties.

Nalhati; 31 and 41¼ pound flange-rails, on teak, sâl, and pine ties.

Lucknow-Sitapur-Sihraman; 41¼-pound steel rails.

Amritsar-Pathankot; 62-pound rails.

Darjeeling-Himalayan; 30 and 40 pound rails, on wooden ties.

Deoghur; 36 pound steel rails, on wooden ties.

Dibru-Sadiya; 41¼-pound steel rails.

Bengal and Northwestern; 41¼-pound steel rails, on sâl and creosoted pine ties.

Rohilkund-Kumaon; 41¼-pound steel rails, on sâl and jungle-wood ties.

Pondicherry; 40.3-pound rails, on wooden ties.

West of India Portuguese; 62-pound rails, creosoted pine, sâl, and teak ties.

H. H. the Gaekwar's; 30-pound flange rails, on wooden ties.

Rajpura-Bhatinda; 68-pound steel rails on deodar ties.

TIES.

Denham-Olphert's cast-iron plate ties (See plates Nos. 21 and 23).—This tie consists of a pair of cast-iron plates, each having a chair for one rail, with a wrought-iron tie-bar connecting them. It is interesting to note the extent to which cast-iron has been employed with successful results—as on the East Indian Railway. On the guaranteed railways of 5 feet 6 inches gauge the plates are oblong, 34 inches by 12 inches, the greater length being transverse to the track. The thickness at the middle is three-fourths inch, tapering to three-eighths inch near the edges, while at the edge it is five-eighths inch. On the bottom, parallel with the rail, is a segmental rib 1½ inches deep at the middle. At the middle of the plate are the jaws which form the rail chair, from each of which run two ribs 3$\frac{9}{16}$ inches high at the jaw and curving down to the edge of the plate. The rails are of double-headed section and are suspended in the chair by the under side of the head resting on the jaws of the chair. The outer jaw is a part of the plate casting, but the inner jaw is loose and is held in place by a flat taper key or cotter driven horizontally through slots in the plate ribs, the tie-bar and a web projecting from the back of the jaw; the cotter is 10 inches long, 2 inches and 1⅝ inches wide, and three-eighths inch thick. With this fastening no wooden keys are used to fasten the rail, which is an important feature in hot countries. The tie-bars are flat, 2½ inches deep by one-half inch thick; they rest on the upper surface of the plates and pass under the rails through both jaws of each plate. They are secured on the outside of each plate by a gib, and on the inner side by the cotter, which holds the several parts together and brings the loose jaw firmly home against the rail. The height from the top of plate to the top of the jaw is 7⅝ inches, and the metal in the jaw is about five-eighths inch thick.

For the meter-gauge lines the plates are 24 inches by 10 inches, with a tie-bar 1½ by ½ inch; the plates are nine-sixteenths inch thick at the middle, three-eighths inch at the sides, and one-half inch on the edges. The rails being of flange-section, the chairs are of different shape from the above; the outer side of the chair has two lugs which hold the rail flange, while the loose jaw on the inner side is of ┏ form, the horizontal portion bearing on the rail flange; the jaw is held in place by a key, as above described. The weight is as follows:

	Pounds.
Cast-iron:	
Two plates	89½
Two jaws	5¼
Wrought-iron:	
Tie-bar	11¼
Two cotters	2¼
Two gibs	½

In another form of the tie for meter-gauge lines each rail rests on a block of wood 5 inches long, 7 inches wide, and 2½ inches thick. The top is cut to give the rail an inward cant of 1 in 20. The rail is fastened by two bolts; the heads are on top, with washers, which hold the rail flange, and the nuts are on the under side of the plate, being prevented from turning by lugs on the plate. The bolt is screwed down through the nut. The tie-bars are only 2 feet 7⅝ inches long, resting on the inner side of the plate and having a notch which engages with a projection on the plate. On the inner edge of each plate is a lug with a slot, through which the tie-bar passes, and a taper key placed on edge is driven into this slot along the top of the tie-bar.

The "Denham-Olpherts-Molesworth" tie for meter-gauge lines is similar to the first type described for this gauge, but has the corrugated wedge fastening designed by Sir G. W. Molesworth and described under the heading of the Indian State railways. Another modification in these ties is the mode of adjusting the gauge by means of the tie-bars. Under the raised rail seat are two studs in the plate. They are placed side by side and are of different dimensions. The end of the tie-bar projects under the rail and has a notch on the lower edge to fit over the projections or studs. When the tie-bar is placed with its ends fitting on one diagonally opposite pair of studs the gauge is 3 feet 3⅜ inches for tangents. When the ends fit over two opposite studs the gauge is 3 feet 3¾ inches for easy curves. When the ends fit over the other diagonally opposite studs the gauge is 3 feet 4⅛ inches for sharp curves. The weight is as follows: 2 plates, 100 pounds; 2 jaws, 5 pounds; 2 wedges, 4 pounds; 1 tie-bar, 10 pounds; total, 119 pounds. This type is also suitable for broad-gauge lines.

The ties take the same depth and level of ballast as the wooden ties, so that by inserting a plate tie whenever a wooden tie is removed the renewal can be carried out gradually without closing the line in sections or in any way interfering with the traffic. The ties have a very long life, and some have been exhibited at Calcutta over which 16,000,000 tons of traffic had passed without causing appreciable wear or injury. The percentage of breakages is very small, and when broken or worn out the plates have still the value of scrap iron, about 30 rupees ($6) per ton at any large foundry. The price in India, when imported, is about 6 rupees 8 annas ($2.16), but when of home manufacture the price will be about $2 per tie complete. The ties are said to make a very smooth and easy riding track, with no jolting or rattling with trains traveling at high speed. Some of the ties on a broad-gauge line, with 74-pound rails, were carefully examined after three years' service and found to be in perfect condition, though about 12,000,000 tons of traffic had passed over them at various speeds.

As regards maintenance, it has been stated that during the first year the amount of labor is slightly greater for track laid with "Denham-Olpherts" ties than for a good track on wooden ties; during the second year it is about equal, or a little in favor of the metal track, while during subsequent years it is much less for the track on metal ties than for that on wooden ties. The following are stated to be the comparative proportions of the cost of renewals per mile per annum:

Creosoted pine	$750
Deodar	625
Sâl	500
Denham-Olpherts	40

The breakages in handling are said to be less than one-eighth of 1 per cent., and one-half of 1 per cent. per annum in the track, against 2 or 3 per cent. for bowl ties.

The ties are generally laid eleven to a rail length of 30 feet; the ballast is usually 2-inch to 4-inch hard stone, but broken brick, ashes, gravel, dirt, etc., are used. The ties are found to be sufficiently elastic for smooth running of trains at high speeds. The weight of the ties for broad-gauge lines laid with 75-pound rails is about as follows:

	Pounds.
2 cast-iron plates	175
2 cast-iron jaws	22
2 wrought-iron cotters	2½
2 wrought-iron gibs	⅝
1 tie-bar	22⅛
Total	222¼

The following is an abstract of a statement submitted to me in June, 1888, by Mr. Browning, the London agent for the patentees:

Mr. C. H. Denham is the engineer-in-chief of the East Indian Railway and Mr. Olpherts was a district engineer on the same line. Several years ago large quantities of cast-iron bowls were sent out from England for use on the East Indian Railway, having been already used with success on the Egyptian railways and in parts of India where the ballast was of sand or light gravel. The East Indian Railway was ballasted for a great part of its length with hard red iron stone mixed with clay. This ballast soon shaped itself under the bowls and became hardened into solid concretcakes, so that it was found that the bowls were constantly getting broken by concussion with the solid blocks of ballast on which they rested. To obviate this trouble Mr. Denham designed a cast-iron tie of about equal weight with the bowls, but formed of flat plates with vertical ribs so arranged on the upper surface as to strengthen the plate and form a seat for a wooden cushion to which the ordinary chair was bolted. Such plates laid in pairs connected by wrought-iron tie-bars were tried, with satisfactory results. The under side of the plate being flat admitted of easy and solid packing, and the proportion of breakage in the track was at once reduced to about one-one-tenth of that of the bowls, while the trains were found to run more smoothly. The principle of a flat iron plate tie having been thus established, improvements in detail rapidly followed. The formation of the outer jaw on the plate and the keying up of a loose inner jaw against the rail by a cotter passing through it and the webs of the rail seat were designed by Mr. Olpherts, and finally the wooden cushions upon which the rails rested were abandoned and the rails were suspended by the under side of the head resting upon the tops of the jaws. In this form the tie had, in June, 1888, been in use for about seven years on the East Indian Railway and other railways in India. The tie is also adapted for flange rails and has been used on the meter-gauge railways of India, which are laid with steel flange rails weighing 41½ pounds per yard. Up to June, 1888, more than 2,000,000 pairs of plates for double-headed rails, and about 600,000 pairs for flange rails had been made, and their use was extending rapidly. The saving in cost of maintenance on the main track of an Indian railway laid with 75 or 80 pound double-headed steel rails on these ties as compared with the same road laid on the best wooden (sâl) ties has been found by experience, extending over several years, to be about $400 per mile per annum. Some engineers still prefer the original form of the plate ties on the ground that the wooden cushions give elasticity to the track, but the general opinion is in favor of the latest pattern, in which the rail is suspended and which is free from the serious defects due to the shrinkage and rapid destruction of wood in hot climates. No trouble is experienced in maintaining a good track, and the difficulty of preserving an accurate gauge, which is unavoidable in a track laid with wooden ties, hardly exists in a track carefully laid with the metal ties. Actual renewals are reported to be rare. The plates require rather more frequent packing than wooden ties, but the ballast to be moved is much less. It is generally concluded that the economy found to result from the use of these plates is due to the renewals being so much less frequent than the renewals of wooden ties, and to the fact that a broken cast-iron tie is worth about three-fourths of its original value, while a worn-out wooden tie is almost worthless. About 900 miles of track are now laid with these ties.

Moore's cast-iron ties.—Mr. George E. Moore, deputy consulting engineer for railways, has designed some forms of cast-iron plate ties, the special feature of which is that the ends of the tie-bar support the rails on the inside of the track, the gauge depending on the accuracy of the length of the tie-bars instead of upon the accuracy of the casting. The plates for broad-gauge lines are rectangular, about 33 inches by 12 inches, the greater length being transverse to the track. The tie-bars are of T section, resting between lugs on the plate and secured by keys driven through the lugs and bar. With double-headed rails the end of the bar abuts against the web; with flange rails the end is cut to fit the web and flange. The plates for double-headed rails have a grooved depression, forming a seat for the lower head, and a jaw on the plate holds the rail on the outside; for flange rails there is a flat seat with a cast clip to hold the outer flange of the rail. No arrangements are made for alterations of the gauge. For light-meter gauge lines the tie may consist of the plates and tie-bar only, dispensing with all loose pieces. These ties are placed diagonally to the track, with the rails in place; the plates are then shifted to bring the tie-bar at right angles to the rails, when the notches and lugs engage and make the fastenings.

A suggested form of cast-iron tie somewhat resembles the steel tie of the state railways; it is of shallow inverted-trough section, deeper at the ends, and with a rib under each rail. The middle of the top table is cut away to reduce the weight and facilitate packing. Another suggested form consists of two plates shaped like tennis rackets, but with parallel sides. On the top of the end of the narrow part, or "handle," is a lug, and when brought together these ends abut against one another and are secured by a bolt passing through the lugs. No loose fastenings are used, each plate having two clips for the rail flange; the plates are put diagonally in the track, with the rails resting between the clips; they are then swung around till at right angles to the track, bringing the narrow ends together and causing the clips to overlap the rail flanges. For light lines the narrow part of the plates may be dispensed with and a tie-bar used to connect the plates. It has been suggested that ties of this kind might be made of pressed-steel plates, but Mr. Moore is in favor of cast-iron, as the ties can then be of home manufacture. The plan of using a tie made in two pieces connected in the middle of the track is not new, although Mr. Moore's designs may have some originality; such ties were patented in the United States as early as 1878 (Nos. 207320, 254802, 312881). (See Preliminary Report, Bulletin III, Forestry Division.)

Mr. Moore's latest form of tie (March, 1889) is a cast-iron cross-tie of shallow inverted-trough section, with closed ends, and having a deep corrugation along the middle of its length, and making a groove on top and a rib below. The tie is 10½ inches wide on the bottom, 9 inches wide on top, and 1½ inches deep at the sides and middle groove; the groove is 1 inch wide. The sides and groove are one-fourth inch thick and the top three eighths-inch thick. At each end of the tie are two rigid rail clips, no loose pieces being used, and the fastening being effected through a certain amount of spring in the rail. This plan is claimed to be particularly suited to light railways of narrow gauge, as the rails can be easily sprung into place by the use of a bar. For broad-gauge lines with heavy and stiff rails one of the two lugs at each end of the tie must be made to turn to some extent round a bolt or rivet, but here, also, the locking is to be done by springing the rail. The movable clip has a projection on the side opposite to the rail to enable a claw-bar to be used to move the clip on or off the rail flange. Arrangements may be made for adjusting the gauge at curves, but Mr. Moore does not consider that this is necessary in ordinary country. For heavy lines it is proposed to use an outer fixed clip 2¼ inches square clear of the rail, with a lip one-half inch by one-half inch projecting over the rail flange; the inner clip is of the same size, fastened by a three-fourths-inch rivet with a one-eighth-inch washer under the tie; this clip turns slightly on the rivet. An oval hole for tamping is provided on each side of the rail.

Bell's cast-iron tie.—The tie designed by Mr. Horace Bell is a flat cast-iron plate tie, intended for meter-gauge lines with flange rails. The plates are 24 inches long and 10 inches wide, the greater length being transverse to the track; the thickness is five-eighths inch at the middle, tapering to three-eighths inch, and on the under side of the plate are two ribs 6 inches apart, parallel with the rail. The rail rests on an elevated seat with a projecting lug on each side; a key of malleable cast-iron of ┏ section, tapered 1 in 100, is driven between the lug and flange on one or the other side of the rail according to the gauge; the vertical web of the key rests in a notch in the rail seat and tie-bar. The tie-bar is of ⊥ section, 1¼ inches deep, 1 inch wide, and one-half inch thick; it rests above the plate, passing through lugs and under the rail; when in position the lower leg of the key engages with a notch in the upper edge of the bar. In another of Mr. Bell's ties there is but one rib on the bottom, and on the top are four ribs running from the raised rail seat, one to each corner of the plate. The tie-bar is flat, 1½ by ½ inch.

Denham's cast-iron tie.—This consists of two cast-iron plates, 34 by 12 inches; a wrought-iron tie-bar 4 feet 6 inches by 2 inches by ½ inch; two ordinary rail chairs weighing 27 pounds each, and a wooden cushion 14 inches by 7 inches by 1½ inches. The usual wooden keys are used for fastening the rails, and instead of spikes two bolts (with the nuts on top) pass through the plate, cushion, and chair. The tie-bar passes through a lug in each plate and fits over a small stud cast on the plate; it is kept from shifting by means of a split pin. Of 4,000 ties, only one breakage occurred during three years, and that was owing to bad drainage. Stone, gravel, and dirt ballast has been used. These ties are said to give better results than the "Denham-Olpherts" ties for lines where good ballast is not attainable, owing apparently to the use of the wooden cushion between the chair and plate.

SUMMARY FOR INDIA OF METAL TRACK.

Railway.	Bowls.	Cross-ties.	Denham-Olpherts plates.	Total
	Miles.	*Miles.*	*Miles.*	*Miles.*
State railways	225½	1,497¼	296	2,018¾
East Indian	79½		160 762¼	1,001¾
Rajputana-Malwa			50	50
Bengal-Nagpur		554½		554½
Southern Mahratta		500		500
Indian Midland	300		214	514
Dhond-Manmad	145½			145½
Bhopal-Itarsi		6		6
Northwestern	370	600	40	1,010
Oude and Rohilkund	692			692
Eastern Bengal	34		30	64
Jorhat		3		3
Cherra-Companyganj		7½		7½
Madras	800			800
South Indian	140	300		440
Great Indian Peninsula	622			622
Bombay, Baroda and Central India	77½			77½
Delhi, Umballa and Kalka			162	162
H. H. the Nizam's	87	175¼		262¼
Khamgaon	7½			7½
Amraoti	5½			5½
H. H. the Gaekwar's		50		50
Bhavnagar-Porbandar		69		69
Morvi		90		90
Jodhpore		59¾		59¾
Calcutta Port	12			12
Total	3,598	3,912¼	1,714¼	9,224½

These figures are most probably considerably below the actual mileage, owing to the lack of complete returns and to the fact that the returns received do not always give the latest mileage laid. The 160 miles of the East Indian Railway are estimated as the proportion of 325½ miles laid with iron and wooden ties intermixed.

FARTHER INDIA.

In Selangor, one of the protected States of the Malay Peninsula, the native hard-wood ties have not worn well, and in 1888 it was proposed to try some wrought-iron or steel ties. The colonial secretary at Singapore wrote me, however, in June, 1889, that no metal ties had then been laid on the Selangor Government Railway. In 1887, 20 miles of line were completed by the State; the meter gauge Government railway was opened for light traffic in September, 1886, and for regular traffic in January, 1887. There are railways in others of these States (Perak and Sunjei-Ujong), but no returns as to the ties used have been received; probably they are of wood.

CEYLON.

Mr. F. J. Waring, chief resident engineer, wrote in October, 1889, that no metal ties are used. All the ties are of Baltic fir or native or Australian hard woods.

SUMATRA.

On the railway of this island, which is a Dutch possession, steel cross-ties are used. They are of the "Post type" (Netherlands State Railway), and are imported from Holland. At first they were laid only upon the rack-rail section of 16.42 miles, but are now being laid over the entire length of the line 90.20 miles. Early in 1889 a contract was reported to have been made with a firm at Oberhausen for 121,000 ties (4,750 tons) at 2.55 gulden ($1.02) each, free on board, at Rotterdam or Amsterdam, but the agent of the manufacturers of these ties in a list of sales up to September, 1889 (see "Holland"), gives only 100,000 for Sumatra. The railway is of meter gauge, and was built to develop an extensive coal basin in the interior. The rack-rail section crosses a range of mountains, and has grades of 4 and 5 per cent. The engines on this section weigh 20 tons each, and two engines (one at each end of the train) can take a train load of 250 tons over the section at a speed of 6¼ to 7½ miles per hour. The sharp curves on the line necessitate a widening of gauge of .96 inch, which is obtained by the use of three sizes of bolts with eccentric necks.

CHINA.

The only railway at present existing is the line from Kaiping to Tientsin, 85 miles, which is owned by the China Railway Company. It is a standard gauge road (4 feet 8½ inches), with maximum grades of 1 to 300 on the main line and curves of 3,000 feet radius. The track is laid with rails of the Sandberg standard sections, 60 and 70 pounds per yard, with angle-bar joints. The ballast is of broken limestone 2 to 3 inches in size and 9 inches to 12 inches deep under the ties. The ties are of chestnut, costing 60 cents each, and having a life of about seven years. The engines have a weight of 6 tons on each driving-wheel. The traffic is general passenger and freight. The climate is reported to be like Canada. In October, 1888, Mr. C. W. Kinder, the chief engineer, stated that a few steel cross-ties were to be imported from England and tried as an experiment. They were of the type adopted on the Indian State Railways, of inverted-trough section with closed ends, and having two clips stamped up out of the metal for each rail; a serrated steel key holds the rail, being driven between one lug and the flange. The steel is five-sixteenths inch thick, and the weight of the tie 80 pounds. They were coated with tar-paint. The cost was $1.20 each at the works and $1.70 in China. They were thought to be too light for the traffic, and were only to be placed on trial. They were manufactured by Messrs. Bolckow & Vaughan, of England.

A few steel ties of the Tozer type (See "England") were reported as being sent out for trial.

In 1887, when there was considerable talk of American companies intending to build railways in China, a form of track was suggested consisting of metal ties of "Berg-and-Mark" section (See "Germany"); they were to be 6 inches wide on top, 9 inches at the bottom, 2½ inches deep, with the sides vertical for 1 inch from the bottom; top table one-half inch thick, with a rig one half inch thick at the middle, sides one-fourth inch thick. The fastening was to be an adaptation of the Fisher rail-joint fastening; it consisted of a U-bolt with the horizontal part inside the tie and the lugs projecting through it, one on each side of the rail-flange, with washers bearing on the rail-flange and secured by nuts. At joints the washers would hold the flange of the angle-bars, the joints being supported on a tie.

JAPAN.

In May, 1888, Mr. C. A. W. Pownall, chief engineer of the imperial Government railways, stated that a few cast-iron bowl ties were laid when the first lines were built, about seventeen years previous, but they have nearly all been taken up again and hardly any remain in the track. For new lines; timber ties are used exclusively.

SUMMARY OF METAL TRACK FOR SECTION 4.

	Bowls.	Cross-ties.	Denham-Olpherts plates.	Total.
	Miles.	*Miles.*	*Miles.*	*Miles.*
India	3,598	3,912¼	1,714½	9,224½
Sumatra	....	90	....	90
Total	3,598	4,002¼	1,714½	9,314⅛

SECTION 5.—SOUTH AMERICA, CENTRAL AMERICA, AND MEXICO.

ARGENTINE REPUBLIC.

GENERAL REMARKS.—Metal track is the standard form of track in this country, owing to the difficulty of obtaining suitable timber in sufficient quantities. The most generally used type consists of cross-ties composed of cast-iron bowls arranged in pairs and connected by a transverse tie-bar. Within the last few years, however, steel cross-ties have been introduced. Since 1888, about 700,000 steel ties of the "Post" type (See "Holland") and about 20,000 tons of the Tozer steel ties (See "England") have been contracted for. Mr. Griswold, writing from Buenos Ayres in July, 1888, said in regard to metal ties: "We use nothing else here, except in the far north and west." The timber ties used in the northern part are principally of "quebracho colorado," which is a very hard timber; the spike holes are bored, and square spikes with rounded ends are driven in. It is almost impossible to draw these spikes. The timber, however, is very inflammable, and the ties are therefore covered over with the ballast. Suitable material for proper ballast not being available, the surface soil is generally used, being well tamped and packed into and around the bowls, and with ample provision made for drainage. Between the rails it is about 1 inch below the top of the rail head, and outside the track it is nearly level with the top of the rails. The want of proper ballast is especially felt in the rainy seasons, when the earth soil ballast is frequently saturated or washed out, entailing considerable expense for repairs. The usual gauge of the railways is 5 feet 6 inches.

BUENOS AYRES GREAT SOUTHERN RAILWAY (See plate No. 26).—The following particulars are taken from a full and complete report, accompanied by drawings, furnished in May, 1888, for the purpose of this report by Mr. Sam. Abbott, general manager, and Mr. Henry G. Sketchley, chief resident engineer:

The road has 13.75 miles of double track and 819.50 miles of single track laid with metal ties. The steepest grade is 1 in 91 for a length of .77 mile approaching Buenos Ayres. Generally the ruling grade is 1 in 200, but by far the greater portion of the railway is either level or has very flat grades. The sharpest curve has a radius of 820 feet, but this is quite exceptional, and is close to a station. Generally the curves are extremely easy, being of very long radius. The embankments and cuttings are generally small, owing to the extreme flatness of this country; the highest bank is 21 feet and the deepest cut 13 feet. The various sections of the line were opened to traffic as follows:

From—	To—	Opened.	Length.
			Miles.
Buenos Ayres	Jeppener	Aug. 14, 1865	47.85
Jeppener	Chascomus	Dec 14, 1865	22.60
Altamirano	Ranchos	Mar. 1, 1871	14.88
Ranchos	Salado	May 19, 1871	19.84
Salado	Las Flores	July 1, 1872	40.17
Chascomus	Dolores	Nov. 10, 1874	55.71
Las Flores	Azul	Sept. 8, 1876	67.93
Dolores	Ayacucho	Dec. 7, 1880	79.50
Azul	Olavarria	Mar. 15, 1883	27.10
Ayacucho	Tandil	Aug. 19, 1883	39.10
Olavarria	La Gama	Oct. 2, 1883	58.00
La Gama	El Puerto	May 7, 1884	162.00
Tandil	Juarez	Feb. 1, 1885	53.00
Juarez	Tres Arroyos	Apr. 2, 1886	56.12
Maipu	Mar del Plata	Sept. 26, 1886	79.76
Hinojo	Sierra Chica	June 1, 1887	4 21
Hinojo	Sierra Baya	do	3.48

There is considerable passenger traffic, especially on the double track. The freight traffic consists chiefly of wool, hides, grain, stone (the latter from the Sierras of Tandil and Hinojo), cattle, horses, and sheep. The locomotives are of various types and weights; the heaviest are built by Beyer & Peacock, of England, and weigh 162,680 pounds, with a weight of 24,808 pounds on the driving-wheels.

Mr. Henry G. Sketchley, is the engineer in charge. The ties consist of cast iron bowls on the Livesey system (See "England"); they are of the forms patented in 1870 and 1882. The new pattern is a great improvement upon the old one, which had not sufficient lateral bearing surface, the outer jaws cutting into the flange of the rail and in some places eating it away right up to the web. In the old form of bowls there were recesses carrying hard-wood cushions for the rails to rest on; these became rotten in course of time, and the rail then bore upon the edges of the recess, which cut into the under side of the flange of the rail. The sectional area of the rail being then reduced in two places, the rail became unfit for use much sooner than it otherwise would have done. The inner jaws (for the keys), also being made of cast-iron, frequently broke. All these weak points have been remedied in the new pattern of bowls. The bowls are of cast-iron and weigh 82 pounds each. The joint ties are spaced 3 feet 4½ inches apart, center to center of tie-bars, and intermediate ties 3 feet 7½ inches. No preservative treatment is considered necessary; cast-iron rusts very slowly and the metal is pretty thick. They are manufactured by the Anderston Foundry Company, of Glasgow, Scotland, and the cost in 1888 was $18.50 per ton, delivered free on board at Glasgow. For curves the adjustment of gauge is effected by having the holes in the tie-bars punched a little farther apart to give a widening of from one-quarter to one-half inch, according to the radius of the curve. The tie-bars can be bent, but this is a bad practice. It is certain that the ties have a very long life, but there is not sufficient data at hand to say how long.

The ballast is of black earth, on which the grass is allowed to grow. During the times of floods the grass is a great protection; and during dry weather it also reduces the dust, which is a great annoyance to travelers. The ballast becomes very highly indurated by the compression and vibration of the passing trains, so much so that during floods the earth under the bowls stands up like small pillars, all the intermediate and surrounding earth having been washed away. It becomes necessary, however, to pack the rails with hard-wood ties at such times, as nothing can be done with the earth that has become saturated with water. The rails are of steel, of flange section. As the 58-pound rails become too much worn to allow of their remaining in the track they are being replaced with 70-pound rails. The rail-joints are suspended.

The reasons for adopting metal ties were the difficulty of procuring good hard-wood ties in sufficient quantities, and their greater expense; also, because a more rigid and more satisfactory construction can be made with iron ties. The general results are considered to be most satisfactory. In very wet weather there is certainly trouble with the maintenance of track, but so there would be in the case of wooden ties; the reason being that the earth when wet can not be used for packing in either case. There is no trouble with the rail attachments. Breakages seldom occur. The iron ties are considered more efficient than wooden ties, but as none of the latter are used on this line there is no certain data for a definite conclusion. Wooden ties of "quebracho colorado" cost about $2.25 each. The climate is very variable and humid; consequently wood, especially pitch pine, soon becomes rotten. The rails are certainly too light for the heavy traffic that passes over them, but this will be generally remedied by the introduction of a heavier section of rail. Generally speaking, the road is considered a good one.

The drawings show bowls oval on plan, 26 inches long, parallel with the rail, and 18$\frac{1}{4}$ inches wide transverse to the track (See plate No. 26). The length on top is 21$\frac{11}{16}$ inches, and the middle is depressed like a saucer. The thickness is five-eighths inch on top, five-sixteenths inch on the sides and eleven thirty-seconds inch in the middle. The rail is secured on the outer side by two lugs which hold the rail-flange; the inner flange is held by a cast-iron taper corrugated key, which bears on the web and flange of the rail, and is driven between the rail and a corrugated steel jaw which is let into a socket in the bowl and is inclined toward the rail. This jaw was formerly of iron, cast on the bowl. The tie bar is of wrought iron, 1$\frac{15}{16}$ inches deep by one-half inch thick; it passes through the upper part of the bowl and is secured by a curved cutter 1$\frac{3}{8}$ inches wide, five-sixteenths inch thick, 6$\frac{1}{4}$ inches long on the arc and about 5$\frac{3}{4}$ inches radius. The cotter is under and parallel to the rail, and lies in the saucer-shaped depression in the middle of the bowl. There are eight pairs of bowls to a rail length of 25 feet. The rails now being used are of steel, flange section, weighing 70 pounds per yard; they are 25 feet long, but are to be 30 feet in future; they are 5 inches high, head 2.4 inches wide, 3.45 inches wide over the flange, radius of top table 15 inches, and of top corners one-half inch. The splice plates are of steel, of deep pattern, having a vertical web projecting below the flange of the rail, and being 5 inches deep over all. The plates are 18 inches long, and have four bolt-holes, spaced 4$\frac{1}{2}$ inches center to center; the inner plate has the holes $\frac{15}{16}$ inch by 1$\frac{5}{16}$ inches to fit the shape of the neck of the bolt; the outer plate has holes fifteen-sixteenths inch diameter; the holes in the rail are oval, 1$\frac{1}{8}$ by 1 inch. The Ibbotson patent bolt and nut is used; a bolt seven-eighths inch diameter, with hexagon nut and round washer 1$\frac{7}{8}$ inches diameter. The rail joints are even and suspended. The older rails were of steel, and of similar form; they were 4$\frac{1}{4}$ inches high, with a head 2$\frac{3}{16}$ inches wide, and a flange 3$\frac{1}{2}$ inches wide. The joints are as above described, but the splice plates are only 4$\frac{3}{8}$ inches deep.

The material necessarily used for ballast requires that great care be taken to dispose it so as to drain easily and rapidly. On the outer side of the track it is level with the under side of the rail head, and is then gradually sloped off by three planes at different angles to a width of about 18 feet at subgrade. Between the rails the ballast, at a distance of about 6 feet from the ends of the rail, forms a ridge across the track level with the under side of the rail head; from this ridge it slopes downward in all directions to the drainage channels at the middle and ends of the rails. The channels at the ends are cut right across the road-bed, but those at mid-rail length only run from the middle of the track to one side, being to right and left alternately. In this way a form of surface is given which tends to throw off water and drains rapidly. The greatest depth of ballast, from under the rail heads, is 18 inches; sloping down to 15 inches at the center line of the track, with channels about 6 inches deep. At the rail ends the ballast is about 12 inches deep under the rails.

CENTRAL ARGENTINE RAILWAY (See plate No. 26).—In 1889, the consulting engineer, Sir Douglas Fox, of London, stated that about 640 miles were then laid with metal track. The line is almost entirely laid with ties composed of cast-iron bowls of Livesey's pattern. The extensions which were under construction in April, 1888, were being laid with these ties. There is no ballast proper, the bowls being packed with the black loam of the country. The grades and curves are easy. Speed of trains, about 30 miles per hour. Weight on driving wheels of locomotives, about 6 tons to each wheel. The gauge is 5 feet 6 inches.

The following particulars are from a statement furnished in January, 1889, by Mr. Malcolm Graham, the resident engineer:

> The line is from Rosario to Cordoba, with branches under construction from Cañoda de Gomez to Pergamino and Las Yerbas. The total length was 245.52 miles. The line is very straight and level, having maximum grades of .5 per cent. and curves of 6,560 feet radius. Construction was commenced in 1864 and finished in 1870, the work being done under the supervision of Mr. Graham. The traffic consists of passengers and general freight. The locomotives weigh about 60 tons. The ties are of cast-iron bowls, on Livesey's system, weighing 90 pounds each. They are manufactured in England, are not treated with any preservative process, and cost delivered $1.05 (gold). They are spaced 5 feet 8¼ inches apart, center to center; no special arrangements are made for curves. They are spaced 3 feet 9 inches apart, center to center of tie bars, giving eight ties to a rail length. Their durability is very good. The ballast is of black earth, which is good except in wet weather. The rails are of steel, of bull-headed section, 30 feet long, and weigh 66 pounds per yard; the joints are suspended, and are fastened by straight splice-plates 18 inches long, with four bolts three-fourths inch diameter. The reason for using metal ties is the difficulty of obtaining wood; the general results of the metal track are satisfactory. The climate has no perceptible effect. There is more trouble with maintenance of the metal track than of track on wooden ties, especially in wet weather. Breakages occur in shipment and in cases of derailment. The track on wooden ties is considered to be better, if the wood was only obtainable. The difference in cost depends upon the distance the material has to be carried.

Each bowl is 19¼ inches long, at right angles to the rail, and the depth under the rail is 5 inches. (See plate No. 26.) The tie-bar is of wrought iron 2 inches deep, one-half inch thick, and 7 feet long; it is secured by a flat, curved cotter, 1¼ inches wide and one-fourth inch thick, driven parallel with the rail through the bowl and a notch in the lower edge of the tie-bar. No more bull-head rails are being used, but the extensions are being laid partly with steel flange-rails weighing 80 pounds per yard (on the suburban portion near Buenos Ayres), and partly with similar rails weighing 67 pounds per yard; the latter are $4\frac{13}{16}$ inches high, with a flange $3\frac{1}{2}$ inches wide; they have an inward inclination of 1 in 20. The track was being relaid in 1887-'88 with steel rails 25 feet long, replacing the old iron rails. With this work an extra pair of bowls was put in for every rail length. The outer flange of the rail is held by a lug on the bowl; the inner fastening consists of two pieces, a loose steel jaw and a cast-iron key. The steel jaw is $3\frac{1}{2}$ inches square, three-eighths to five-eighths inch thick; the inner face is corrugated vertically and there are two vertical ribs on the back; this jaw is let into a socket in the bowl and inclines inward at an angle of about 55 degrees, the top being about 1 inch from the web of the rail. The cast-iron key is driven between the jaw and the rail, bearing on the web and flange of the rail.

The weight of the ties is as follows:

	Unit weight.	Total.
	Pounds.	*Pounds.*
Cast-iron bowls with steel jaws	90.00	180.00
Cast-iron keys	5.00	10.00
Wrought-iron tie-bar	23.00	23.00
Wrought-iron cotters	0.84	1.68
Total weight per tie		214.68

The dimensions of the cross section of the line on double-track are as follows: Width at subgrade, 29.50 feet; outside of this at each side is a ditch 18.4 inches deep, 14 inches wide at the bottom, and 22 inches wide on top. The distance between the inner rails of the two tracks is 7.31 feet, and the distance center to center of outer rails is 18.66 feet; the ballast is 12 inches deep between the rails and 18 inches outside, sloping down 3 to 1 to form a drain between the tracks; and on the outer sides it slopes down 3 to 1, the slope being 3 feet 6 inches wide, and leaving a strip 12 inches wide between the toe of the ballast and the ditch.

In regard to the earth ballasting, Mr. Walter Morrison, president of the company, made the following remarks at the annual meeting in London, in May 1889:

> You know that in this country there is no ballast. The sleepers (ties) are just put down on the soil, and when it rains the soil, saturated with water, works up into a puddle, and it is impossible then for the permanent-way (track) men to do anything with the line. It is no use to put more soil under the sleepers to pack them up, because the soil becomes a puddle; and I am afraid that when the rain stops we shall have a heavy bill to pay for damages to the line at the time of the rain-fall.

The rain-fall of the season of the early part of 1889 was said to have been extraordinary in its persistence. Allowance must be made for Mr. Morrison being unacquainted with railway construction when he said that "the sleepers are just put up down on the soil." This might convey the idea that the line was very roughly and cheaply built; but, as has been shown in the description of the Buenos Ayres Great Southern Railway, great care is generally taken to make the best possible roadbed with poor material. From the particulars given above it is probable that similar care has been taken on this line, and Mr. Morrison was only unfortunate in his manner of expressing himself.

BUENOS AYRES AND PACIFIC RAILWAY.—This is one of the railways which is to connect with the Chilian railways and form a transcontinental line. The gauge is 5 feet 6 inches. It is about 426 miles long; for the first 18.6 miles wooden ties (of quebracho-colorado) are used, and the remainder is laid with cast-iron bowls. The bowl, or "copa," is oval on plan, 26 inches long by 18 inches wide across the track, 8 inches deep, and about five-eighths inch thick; they are spaced 4 feet 8 inches apart, center to center of tie-bars. The rails are of double-headed section; the outer side is supported by two lugs, and on the inner side is a wrought-iron lug with a key driven between it and the web of the rail; they are spliced in the usual way.

The following notes are from letters from Mr. F. L. Griswold, published in the Railroad Gazette, New York, May 1 and August 28, 1885.

> *February* 15, 1885.—Track-laying under good organization can be done a third more rapidly than with wooden ties, at least I think so. The rail weighs 56 pounds per yard and is 4 inches high and 3 inches base; it has a bearing of 16 inches on each tie and is clamped at each end of the bearing on the outside and at the middle on the inside. The wrought-iron lug that holds the cast-wedge is corrugated on the inside and the wedge or key on the outside. The tie-rods are put in and keyed up on the ground. Between Buenos Ayres and the foot of the Andes the location is easy; there is one tangent 211 miles long. There are no bridges. The deepest cut is about 3.28 feet and the highest fill about 6.56 feet. The grades are, say, 0.5 per cent., or 26 feet per mile as an outside maximum. Only 96 miles are as yet completed and in operation.
>
> *June* 29, 1885.—We are using a 50-pound English steel rail, with Livesey's patent iron bowls, which give 21 inches of support to 28 inches of suspension, or, in other words, the supports are 21 inches long, and the clear distance between supports is 28 inches; all loam ballast. Over this track we are using engines of about 40 tons on a wheel-base of about 18 to 20 feet as an average of the different styles. The east end of the road has been in use for about twenty months and shows good track and the rails in good condition.

In a personal letter to me in July, 1888, Mr. Griswold stated that he had a deep interest in the movement for forest protection and in the metal tie question. He gave as his opinion that iron or steel ties will supersede wood in nearly all countries, and that a track may be built with them that will possess equal efficiency in all respects with a track on wooden ties.

EAST ARGENTINE RAILWAY.—The following particulars are from a report sent to me in August, 1889, by the president of the Argentine Republic Society of Civil Engineers:

> The line runs from Concordia to Ceibo, a distance of 99.20 miles. There are 12,500 metal cross-ties in use, 2,500 being of iron and 10,000 of steel; metal ties are also used in renewing old wooden-ties. The ties have been laid at different times since 1880 and

the work has been done under the supervision of Mr. Oliver Budge, chief engineer of the railway. The locomotives weigh 30 tons each, and have a weight of 11 tons on the driving-wheels. The iron ties are made by the Le Grange Works in France, and weigh 81.4 pounds each. The steel ties are of the type adopted on the Indian State Railways and are manufactured by the Ebbw Vale Iron and Steel Company, of England; they are 8 feet long by 8 inches by 4 inches; three-eighths inch thick; they weigh 90 pounds each, and 92½ pounds with fastenings. They are spaced 3 feet apart, center to center. They are given a coat of coal tar, and the cost at the works is $1.35 each in gold. On curves eight ties are used to a rail length of 21.32 feet. There is little expense for maintenance, and the ties laid in 1880 are still in good condition. The ballast is of gravel, which becomes consolidated under the ties. The width at subgrade is 16 feet. The rails are of flange section, 4 inches high and 3¾ inches wide; they are spliced by fish-plates and 4 bolts. For 37.20 miles the joints are suspended, and for the remaining 62 miles they are supported on the ties. The metal ties were adopted on account of their greater durability than wood, and the results have been very satisfactory. There is no trouble with the rail fastenings, and breakages are very rare. The steel ties effect a saving of 4 inches of ballast. Hard-wood ties are also used, and cost $1.20 (gold) each. The climate is mild and has very little destructive effect on the ties. The line is 4 feet 8½ inches gauge, has a maximum grade of 1 in 80 (1.25 per cent.,) and a minimum curve of 1,640 feet radius. The rails are secured to the ties by riveted and bolted clips, the inner clip of one rail and the outer clip of the other rail being riveted; the holes are punched cold.

SANTA FÉ AND CARDOVA GREAT SOUTHERN RAILWAY.—This line, which will run from Villa Constitucion to La Carlota, a distance of 186 miles, is now under construction. The track will consist of steel rails of flange section, weighing 65 pounds per yard, laid on steel cross-ties; 21,000 tons of rails and 20,000 tons of steel ties were ordered in 1889. The ties are of inverted trough section, weighing 120 pounds each, and the rails are secured by lugs and keys. They are spaced eleven to a rail length of 32 feet. The rail joints are suspended. The ballast is of earth. Schultz, Tozer & Co., of London, supplied the 365,000 steel ties (20,000 tons), which are for mixed gauge. The two outer rails, for the gauge of 5 feet 6 inches, are of flange section, and are secured to the tie in the same way as on the Indian state railways; the middle rails, for the meter gauge, are of bull-headed section, secured to the self-fastening chairs patented by this firm (See "England"). The steel used is of the quality generally used for the Indian ties; it is equal to a tensile strain of between 26 and 31 tons to the square inch, with a contraction of 40 per cent. at the point of fracture. Mr. E. H. Woods is the engineer.

BUENOS AYRES AND ENSENADA PORT RAILWAY.—This line is 37 miles long, 5 feet 6 inches gauge, and the track consists of steel rails weighing 68 pounds per yard, carried on cast-iron bowls, which are ballasted with the black earth of the country. The line connects the city of Buenos Ayres with the new docks and port at Ensenada; the cost was about $95,000 per mile, there being some expensive works on the first 5 miles and at the crossing of the Riachuelo River. It passes through agricultural and grazing country, and has a large passenger traffic; from Buenos Ayres there is a large traffic of suburban trains. The following note on the respective merits of steel cross-ties and cast-iron bowls (or pots) is taken from the report of Mr. A. R. Brown, general manager, made in October, 1889:

> *Main line.*—This is in good running order throughout. It is interesting to note the superiority of the new transverse steel sleepers that you have sent for the double line over the "pots." I have laid half a kilometer (.31 mile) of the new rails and ties between Barracas and General Mike; they have been down since April, and have hardly required any touching. It is difficult to estimate the enormous saving that may be effected by the use of these sleepers in the personnel of the permanent way; they are especially adapted to the mud ballast of this country, as after rain there is beneath them a tie composed of dry earth, which forms a very rigid road. Their great superiority over the pot is in that they do not sink on one rail which is invariably the case with the pots, which carries a nasty oscillating movement to the train; also that they are not so easily broken."

Buenos Ayres and Rosario Railway.—On this line cast-iron bowls are said to be used as far as Sunchales, a distance of 341 miles, beyond which ties of "quebracho-colorado" wood are used.

Buenos Ayres Northern Railway.—This line has $5\frac{13}{16}$ miles of single track laid with metal track, which was put down between 1877 and 1886. There is ordinary passenger and freight traffic, hauled by locomotives weighing 26 to 48 tons in working order. Mr. T. E. M. Marsh, of England, is consulting engineer. The line has now been absorbed by the Central Argentine Railway. The ties consist of a pair of cast-iron bowls of oval shape 27 by 20 inches, weighing 100 pounds each. They were manufactured by the Anderston Foundry Company, of Glasgow, Scotland, and are treated with Dr. Angus Smith's preservative solution. There are eight pairs of bowls to a rail length of 23 feet. The bowls are connected by transverse tie-bars, with a gib and cotter fastening to each bowl; the gauge can be adjusted or widened by transposing the gibs and cotters. Up to August 15, 1889, the date of Mr. Marsh's communication, no breakages had been reported. The parts of the line where these ties are used are badly provided with good ballast for ordinary wooden ties, and the metal ties are adopted because the ballast is soft and bad for wooden ties of ordinary dimensions. Where wooden ties are used they are of native hard wood, which is good and durable. The rails are of steel, of flange section, weighing 68 and 75 pounds per yard; they are secured by patent cast-iron corrugated keys. The rail joints are suspended, and are spliced by fish-plates 16 inches long, with four bolts.

Western of Buenos Ayres Railway.—This line is about 620 miles long, 5 feet 6 inches gauge. There are Barlow iron rails weighing 88.5 pounds per yard; double-headed rails weighing 64.38 pounds per yard, and steel flange rails weighing 56.34 pounds per yard. The track now used consists of steel rails 26.24 feet long, carried on nine cross-ties of hard wood (quebracho or urunday), or upon seven pair of Livesey's cast iron bowls.

Andine Railway.—This line is 476 miles long, 5 feet 6 inches gauge. The track consists of rails weighing about 54 pounds per yard, carried on cast-iron bowls.

SANTA FÉ AND NORTHERN COLONIES RAILWAY.—This line is 62 miles long, 1 meter gauge. The rails are of steel, weighing 45 pounds per yard. Some of the ties are of the "quebracho-colorado" wood, brought from the Chaco and from Corrientes, but the majority are of cast-iron bowls.

NORTHERN CENTRAL RAILWAY.—This line is about 548 miles long, 1 meter gauge. Iron ties are extensively used.

SUMMARY OF METAL TRACK FOR THE ARGENTINE REPUBLIC.

Railways.	Cast-iron bowls.	Cross ties.
	Miles.	*Miles.*
Buenos Ayres Great Southern	833.25	
Central Argentine	640.00	
Buenos Ayres and Pacific	407.40	
East Argentine		7.10
Santa Fé and Cordoba Great Southern		186.00
Buenos Ayres and Ensenada Port	36.69	0.31
Buenos Ayres and Rosario	341.00	
Buenos Ayres Northern	5.81	
Western of Buenos Ayres (estimated)	250.00	
Andine	476.00	
Santa Fé and Northern Colonies	60.00	
Northern Central (estimated)	300.00	
Total	3,350.15	193.41

CHILI.

GENERAL REMARKS.—In November, 1889, "Industries," and some other European engineering journals, reported that the Chilian Government, through its legation at Paris, France, was negotiating for 739,400 metal ties 9 feet long, and 725,100 ties 4.25 feet long. Mr. Henry Budge, chief engineer of the State railways, has stated that there must have been some mistake, no such proposals having been asked for by the Government. Mr. C. M. Seibert, secretary of the United States legation at Santiago, stated in January, 1889, that there were 679.52 miles of lines owned by the Government, and 965.96 miles owned by private parties or companies, a total of 1,645.48 miles. Some new lines are being built. He also stated that Chili possesses abundance of forests in the southern part of her territory, sufficient for supplying railway ties for many years.

COQUIMBO RAILWAY.—In a letter dated August 4, 1888, Mr. Henry A. Vivian, chief engineer, stated that in 1887 he received from England sufficient steel ties to lay one mile of track, but so far very few had been put in. They were steel cross-ties, of the type adopted for the Indian State Railways, 9½ inches wide at the bottom, and having an extra thickness of metal on the top. They were for a gauge of 5 feet 6 inches, and weighed 120 pounds each. They were not what he wanted, and as their weight made them very expensive he decided not to ask for any more. They cost $8 each, in Chili currency, while timber ties, having an average life of about five or six years, could then be bought for $1.30. Cypress ties are used.

BRAZIL.

General Remarks.—In this country, metal ties have only been tried to a limited extent. Mr. Jason Rigby, chief engineer of the Great Western of Brazil Railway, in a letter dated May 17, 1889, stated that there were two reasons for the non-employment of metal ties: First, because the Government, wishing to encourage the use of native material, has objected to their use; second, because the native hard wood can be obtained at a very low price. Mr. O'Meara, of the Brazil Great Southern Railway, stated that no iron or steel ties are in use on that road, as native timber of good quality is obtainable at moderate prices along the Uruguay River. The following table of the mileage of Brazilian railways is from the official returns for December 31, 1887:

Railways.	In operation.	Under construction.	Surveyed.
	Miles.	*Miles.*	*Miles.*
State lines	1,248.06	155.00	1,463.82
General Government, guaranteed lines	1,602.70	118.42	13.02
Provincial government lines	58.90	....	93.00
Provincial government guaranteed lines	962.24	301.32	475.54
Companies without guarantee	1,337.34	286.44	184.76
Total	5,209.24	861.18	2,230.14

Great Western of Brazil Railway.—Mr. Rigby, the chief engineer, stated as follows in a letter dated May 17, 1889:

> A short time since, when building an extension of this line, I thought of introducing steel ties as even the best native hard wood only lasts in this climate from six to seven years. I got some samples of different systems sent out, but all were, in my opinion, objectionable either from complication of the rail-fastenings or want of sufficient length outside the rail to give stability in the very soft sand ballast which is all we can obtain here; and then the price, with freight and duties, put their use quite out of the question. I pay here 50 cents for a squared tie, 7 feet by 9 inches by 5 inches, all hard wood, delivered on the line.

Southern Brazilian Rio Grande do Sul Railway.—The following particulars are from a statement furnished in December, 1889, by the consulting engineer, Mr. Charles Neate, of London:

> The line has curves of 328 feet to 6,560 feet radius, and grades from 3 per cent. to .025 per cent. About .62 mile of metal track was laid between 1880 and 1884. Mr. A. Duprat is the general manager and Mr. Baras de Holleben is resident engineer. The engines are of two classes: (1) ten-wheel engines with tenders, with six coupled wheels and a four-wheel leading truck; 23 tons total weight with 5,936 pounds on each driving-wheel; (2) eight-wheel engines, with tenders, with six coupled wheels and a two-wheel leading truck; 23 tons 448 pounds total weight, with 7,504 pounds on each driving-wheel. The ties are of steel, of the Indian State Railway pattern, for 1 meter gauge. They are 5 feet 6 inches long, 8¾ inches wide, with closed ends 4½ inches deep; 12 inches wide, 1⅜ inches thick on top: the weight is 70 pounds per tie. The rails are secured by lugs and keys. The ties are spaced 24 inches apart, center to center, at joints, and 31½ inches apart, intermediate. There are 5,000 ties manufactured by the Darlington Steel Company, England; they are given a coat of paint and cost about $1 each. The rails are of flange section, weighing 40 pounds per

yard; the joints are suspended, and are fastened by splice bars and four bolts. The ballast is of coarse sand, and occasionally small stone; no gravel proper is to be had; it is about 13 inches deep. With wooden ties it is very liable to be washed away by the tropical rains, but there is no sufficient experience yet with the hollow metal ties. The steel ties were tried on account of the early decay of native hard-wood ties, the life of which rarely exceeds five years in the northern provinces, and eight to ten years in the southern provinces. The general results are satisfactory, so far as is known, especially for preserving the gauge on sharp curves, but the time of the test has not been long enough to enable any definite opinions to be formed. Careful maintenance is necessary, but there is little trouble with the rail fastenings. Native hard-wood ties cost 60 to 72 cents each, delivered.

Although the forests of Brazil undoubtedly furnish hard wood of the finest quality, ties from which would be very durable, the cost of obtaining such ties for the whole line would be almost prohibitory; whereas with metal ties uniformity of quality can be obtained at a moderate cost, and it is expected that the steel ties will prove durable. Cast-iron bowl-ties will undoubtedly last well, but on railways of 1 meter gauge, where the rolling-stock is necessarily wide in proportion to the gauge, cross-ties are found to give more lateral stability than bowl-ties. The Indian pattern of steel cross-ties admits of a certain widening of gauge round curves, if necessary, by shifting the keys to the outer side of the rails, or by the use of special keys.

CONDE D'EU RAILWAY.—The following particulars are from a statement furnished in December, 1889, by the consulting engineer, Mr. Charles Neate, of London. (For general notes see the preceding paragraph on the Southern Brazilian Rio Grande do Sul Railway.)

The line has a maximum grade of 2.22 per cent., and the minimum curves of 328 and 394 feet radius. There are about 20.46 miles of metal track, laid between 1880 and 1884, under the supervision of Mr. I. H. P. Dunsmure, general manager and resident engineer. There are three classes of locomotives: (1) new tank engines, four coupled wheels and a four-wheel truck, 26 tons weight in working order, with a maximum weight of 4½ tons on each wheel; (2) tank engines, with four coupled wheels and a Bissel or pony truck, 21 tons in working order, with 4 tons on each coupled wheel; (3) eight-wheel engines with tenders, four coupled wheels and a four-wheel truck, 21 tons in working order, with 3½ tons on each coupled wheel. The ties consist of a pair of cast-iron bowls weighing 65 pounds each; each bowl is oval, 22¼ inches long, 18¼ inches wide, 4¾ inches deep, with a metal three-eighths inch and one-half inch thick on the sides and three-quarters inch on top. The tie-bar is secured by a gib on the inner side and a cotter on the outer side of each bowl. The rails are of steel, of flange section, weighing 50 pounds per yard, they rest on two wooden cushions on each bowl; the inner side of the flange is held by a lug, and on the outer side an elm key is driven between the web of the rail and a high lug on the bowl. The ties are spaced 3 feet 10 inches apart. The bowls are manufactured by Head, Wrightson & Co., of Stockton-on-Tees, England, and cost about 68 cents each. They were used by the contractors owing to the scarcity of native timber.

DONNA THEREZA CHRISTINA RAILWAY.—The following particulars are from a statement by Mr. Charles Neate, of London, the consulting engineer, furnished in December, 1889. (See also the two preceding railways.)

The line has minimum curves of 328 feet to 392 feet, and maximum grades of 2.22 to 1.66 per cent. About 2.48 miles were laid with metal track between 1880 and 1884, under the supervision of Mr. E. J. Brown, general manager and resident engineer. The engines are eight-wheel tank engines, with six coupled wheels and a two-wheeled leading truck with radial axle boxes; they weigh 22 tons in working order, with 2½ tons on each coupled wheel. Two patterns of cross-ties have been used; in the first instance, 1,000 steel ties manufactured by Howard & Company (See "England") were sent out, and subsequently 5,000 steel ties of the Indian pattern, as already described for the Southern Brazilian and Rio Grande do Sul Railway. The "Howard" ties were 5 feet 6 inches long, 10 inches wide on the bottom, and 3 inches deep with metal three-sixteenths of an inch thick; they weighed 40 pounds each and cost $1.20 each. The spacing weight, maker, and cost of the Indian pattern ties are as already described. The rails are of flanged section, weighing 40 pounds per yard. The reasons for trying metal ties were the same as on the Southern Brazilian line.

The Howard tie was not of the heavy type for main lines; a corrugation or rib was formed along the top of the tie, and pressed down at the rail-seat to allow the flange of the rail to rest on the flat portion of the top of the tie; the sides of the rail-seat formed clips for the rail flanges, and the rails were secured by steel keys driven between one clip and the rail flange.

RECIFE AND SAO FRANCISCO PERNAMBUCO RAILWAY.—Ties of iron and native hard wood are used on this line.

DOM PEDRO SEGUNDO RAILWAY.—On this line (now known as the Central Railway of Brazil, since the change of government from an empire to a republic) some wrought-iron or steel cross-ties of inverted trough section, similar to those of the original Vautherin section, were in use as an experiment near Rio, in 1888, and were there noticed by Mr. Rigby, of the Great Western of Brazil Railway.

SAN PAULO RAILWAY.—This line runs from Santos to Jundiahy, about 62 miles, and has two grades of 2½ per cent., and curves of 984 feet radius. The traffic is chiefly heavy freight; the engines weigh 44 tons, with 11 tons per axle. Mr. John Barker is the engineer. The ties used are of the old form of Greaves's cast-iron bowls, arranged in pairs and connected by tie bars. The bowls are 22 inches in diameter, with metal one-half inch thick, and weigh 176 pounds per tie. They are coated with tar. They are spaced 2 feet 9 inches apart and are connected by tie bars 2 inches deep by three-eighths inch thick. They are manufactured in England and cost $22.50 to $24 per ton. Their average life is twenty-five years, and the expense of maintenance is small. There is no trouble with the rail attachments, nor from breakages, and the efficiency is said to be five times as great as that of wooden ties. The rails are of bull-headed section weighing 66 pounds per yard and have suspended joints. Metal ties were adopted on account of the economy resulting from their use, and the general results have been satisfactory. They make a rigid but very economical track, although the first cost is double that of wooden ties.

MINAS AND RIO RAILWAY.—In a letter dated May 27, 1889, Mr. F. E. Fenn, general manager, stated that there were no metal ties then in use, but that an experiment was about to be made with steel ties. Messrs. Brunlees & McKerrow, of London, the consulting engineers, report that these ties will be of the type adopted on the Indian State railways, and will be laid for a length of about .62 mile.

SUMMARY OF METAL TRACK FOR BRAZIL.

Railways.	Bowls.	Cross-ties.
	Miles.	*Miles.*
Southern Brazilian Rio Grande do Sul		.62
Conde d'Eu	20.46	
Donna Thereza Christina		2.48
San Paulo	62.00	
Minas and Rio		.62
Great Western of Brazil*		
Recife and Sao Francisco Pernambuco*		
Dom Pedro II*		
Total	82.46	3.72

*Experimental trials.

VENEZUELA.

General Remarks.—The contractors who built the Puerto Cabello and Valencia Railway and the Bolivar Railway (Messrs. Perry, Cutbill, and De Lungo, of London), and who have had large experience in railway construction in South America, state that their general impression is that track constructed with iron ties is more expensive to keep in order, but at the same time is certainly more durable than track with wooden ties. The engineer of this firm considers that for sharp curves heavy wooden ties are the best, if of hard and durable timber. Steel he considers better than creosoted pine, but inferior to vera, jarrah, and similar hard woods. His opinions as to the comparative work of maintenance with track on metal and wooden ties differ from those usually expressed. Mr. James T. McGawran, resident engineer for railways being built by a French company, stated in August, 1889, that while he had not been connected with any railway using metal ties, he considered that they would prove useful where timber is scarce (as in the Argentine Republic), or in places like Venezuela, provided that lignum-vitæ and one or two similar timbers can not be obtained, where the white ant (comahen) will make short work of any ordinary wooden tie. He is fortunate in being able to get a wood (curarire) which lasts from twenty to thirty years. It is true that each tie has to be bored, but as the system of track-laying is that adopted extensively in Europe, the rails being secured by screw-spikes, this makes no difference, as the holes would have to be bored in any case.

Puerto Cabello and Valencia Railway.—On this road (also known as the Venezuela Central Railway), which is 34 miles long, steel cross-ties are used on an incline 2¼ miles long, with a grade of 8 per cent. and curves of 500 feet radius. This incline is operated on the Abt rack-rail system; the rack-rail being carried in chairs fastened to the ties. The traffic consists of passengers and freight, and the trains are hauled by locomotives weighing 40 tons, with a load of 13 tons per axle. The ballast is of broken stone. The rails weigh 56 pounds per yard. Metal ties are used to avoid renewals, and the general results have been satisfactory. There has been no trouble with the rail attachments, nor from breakages, but there has been trouble with the maintenance. It is reported that the track with wooden ties is more easily kept in condition, but the difference is not very great.

BOLIVAR RAILWAY.—This line (known also as the Quebrada Railway) was built in 1875; it is 55 miles along, with generally very easy grades and curves. The traffic is heavy, principally mineral; the engines weigh 20 tons and have a load of 7 tons per axle. The steel cross-ties originally laid are reported to be still in good condition. There is no proper ballast. The rails weigh 30 pounds per yard. No trouble has been experienced from breakages or with the rail attachments. There has, however, been trouble with maintenance, and it is reported that the track is more easily kept in order with wooden ties, but the difference is not great. The line is of 24 inches gauge. The ties were made by Kerr and Stuart, and have riveted clips which support the outer side of the rail head like rail braces. (See "England.")

LA GUAYRA AND CARACAS RAILWAY.—This line is 23 miles long. It has been stated that cast-iron bowls are used for ties; but no returns have been received, no reply has been made to requests for information, and no reliable or definite information on this point has been obtained. As Mr. James Livesey is the consulting engineer, it is quite probable, in view of the statement above referred to, that the Livesey system of track with cast-iron bowls is employed. (See "England.")

Summary for Venezuela.

Railways.	Bowls.	Cross-ties.
	Miles.	*Miles.*
Puerto Cabello and Valencia	....	2.25
Bolivar	....	55.00
La Guayra and Caracas	23	....
Total	23	57.25

UNITED STATES OF COLOMBIA.

GENERAL REMARKS.—Mr. F. J. Cisneros, an engineer who is connected with the Bolivar Railway of Colombia and a number of other railways, stated in May, 1888, that he was an advocate of metal ties and had thought of employing them, but so far he had no experience with them.

PANAMA RAILWAY.—Metal ties have not been used, as hard and long-lived wooden ties are available. An engineer who has been over the road remarked that in such a climate, and with the class of labor available, there would probably be trouble with the maintenance and fastenings of metal ties for the first few years, owing to the indolent and careless nature of the trackmen. It may be remarked, however, that after the first few years the maintenance is generally found to be considerably less with metal ties than with wooden ties. Mr. W. F. Dennis, acting general superintendent, wrote as follows in June, 1889:

> On our road, 47 miles, we have never had either steel or iron ties under our track. Our main line has lignum-vitæ ties about 6 by 8 inches in sections, which are supplied from the surrounding countries at a cost to us of from $1.50 to $1.80 gold each. These ties are so hard as to necessitate boring holes for spikes, but after the preliminary difficulty is overcome they make an extremely solid and durable track. It is difficult to get exact information as to the life of these ties, but it is a common saying among trackmen that these ties are good for twenty-five years, and there are instances where ties have been recently taken up which have been in track a long time; it is even claimed that they have been in use since the opening of the road, nearly thirty-five years ago. Ordinary timber, such as pine and oak, when subjected to exposure, is not good for more than three years at the utmost.

GUATEMALA.

GUATEMALA CENTRAL RAILWAY.—Under the ownership of Mr. C. P. Huntington it had been proposed to try metal ties, but no definite steps were taken, and the road having now passed into other hands it is not probable that any such steps will be taken in the near future. The following are extracts from a detailed communication from Mr. William Nanne, general manager, dated in May, 1889:

> The subject to which you are applying your energies certainly deserves the attention of all true railroad men, not only on the continent but all over the world, because it is only a question of time everywhere when the time-honored wooden substructure will have to give place to the iron age. We Central American railway constructors, in tropical jungles, with any amount of hard or soft wood ties presumably at our disposal, make a poor show in this important question of economical construction and operation, and nowhere, perhaps, has the adoption of metal cross-ties been more seriously considered than on our lines, but we have not as yet arrived at the practical application, for reasons given later. For these reasons I have held back from the experiments suggested by Mr. Huntington and Mr. Mahl. We are using about half California redwood ties, 8 feet by 8 inches by 7 inches and 7 feet by 7 inches by 6 inches; and the balance native hardwood ties 6 feet by 7 inches by 6 inches, and 6 feet by 8 inches by 6 inches. All of these have an average life of six years under new track. On the mountain division we are rising on our present location 2,600 feet in 12 miles, with curves of 15 degrees and on several trestles 150 feet high. By great care we have operated this without the slightest accident, but it is such costly operation that we are now lengthening the division to 16 miles, with a maximum grade of 3 per cent.; we are about two-thirds through with the work. In preparing for this work the question of the use of metal track was seriously considered, and Mr. Huntington seemed to favor the use of steel cross-ties. But much as I appreciate the "Post" system (See "Holland") as the best so far brought out, I have objected to even an experiment on our crooked line and heavy grades, which in many places are on the borders of tremendous precipices. In none of the metal ties do I see how the proper widening of the gauge or curves is to be carried out, and this is the main obstacle I see to our adopting metal ties. Another consideration is that the cost of transportation of material to our Central American lines, via Cape Horn, comes to about 200 per cent. on the original invoice, with heavy landing expenses of $10 to $20 per ton at our Pacific terminal station; bringing the cost of a Post steel tie, placed on our line, to about $3 to $4 silver (35 per cent. discount on United States gold). You will agree with me, as our board has agreed already, that under these circumstances, when we can get good wooden ties for about $1 silver per tie (or say

75 cents United States gold), lasting six years on an average, we are not yet up to the metal track question. Nevertheless the question is watched very closely by me and I am always open to conviction if I can see my way clear. So far I shall stick to the time-honored wooden ties for elasticity and safety generally.

The road is 75 miles long, with maximum grades of 3 per cent. and minimum curves of 15 degrees. The ties are spaced 24 inches apart, center to center, and are laid in broken stone and blue gravel ballast. The rails are of steel, weighing 54 pounds per yard; the joints are even and suspended, spliced by angle bars 20 inches long. Ajax steel braces are used on curves. The engines weigh 45 tons. Mr. Albert J. Scherzer is the engineer in charge. In regard to the question of adjustment of gauge I have already referred to the importance of this matter, and it will be seen that a wide range of adjustment combined with very secure fastenings is required on such a crooked road. Probably the Ruppel system of fastening, as used in the Prussian state railways (See "Germany") would meet the requirements.

COSTA RICA.

General Remarks.—Mr. Manne, of the Guatemala Central Railway, states that he believes that steel ties are being used on these lines. Over 100 miles of railway are in operation, and several lines are under construction.

SAN SALVADOR.

General Remarks.—It has been reported that it is proposed to use steel ties of American design and manufacture on a new railway to be built.

MEXICO.

General Remarks.—Metal ties have been tried and have given such good results that their use is being extended.

Mexican Railway.—The Mexican Railway (Vera Cruz line) has now in service several miles of track laid with steel ties of the type designed by Sir A. M. Rendel, and adopted for the Indian state railways. The length of the main line is 265 miles. At the end of June, 1888, there were 46¼ miles laid with steel-ties, and at the end of June, 1889, there were 77 miles laid with them. While they have not been in service long enough to test their durability they have given great satisfaction, particularly by their behavior in times of flood. In regard to breakages, I am credibly informed that in one case a Baldwin consolidation engine left the rails and traveled about 100 yards over the ties without breaking a single one; some were bent, but were easily put into shape at the shops. The line has grades of 2 per cent. The locomotives are Fairlie (double-boiler, double steam-truck) engines, weighing 80 tons, and Baldwin consolidation engines. The ties are made in Wales, weigh 112 pounds each, are treated with a coal-tar preservative composition, and are spaced in the track 2,000 to the mile. The rails are of flange section, weigh 62 and 82 pounds per yard, and are secured by steel keys, as on the Indian state railways. The joints are supported on the ties, and are spliced by ordinary fish-plates. The general results have been satisfactory, the efficiency being much higher than with wooden ties; there has been no trouble with maintenance of rail attachments nor from breakages. In August, 1889, proposals were opened at the London office of the company for 10,000 of these ties, to be used with 62-pound rails. Mr. J. F. O'Brien, general manager of the Mexican National Railway (since resigned), stated in August, 1889, that no experiments had been made on his road, but that on the Mexican Railway the results of the steel-ties seem so very satisfactory that it has been decided to substitute them for wood entirely. He has been over the line several times, and states that the track on metal ties seems to be very smooth and perfect, even in the rainy season, and he sees no reason why they should not be a success after the experience of this railway. There is said to be even less noise and greater smoothness in riding over the track with steel ties than the track with wooden ties.

The following is taken from a paper on "The Railways of Mexico," by Mr. W. B. Parsons, read at the annual convention of the American Society of Civil Engineers in June, 1889:

> The most interesting thing in connection with the track is the use of metal cross-ties. Wooden ties, expensive in first cost, were found to last only four or five years, so that metal was adopted for economy. The ties are of mild steel, and weigh 110 pounds each. The rail is held by clamps punched up from the tie, and is secured by a key weighing 1 pound; so that a tie and two keys weigh about 112 pounds. In section they are channel-shaped, with an extra thickness of metal on the top. The ends are splayed and turned down so as to retain the ballast, while the tie is bent upwards toward the ends so as to give the rails an inward cant. Their price varies with the price of steel, but is now about 5 shillings (English), or say $1.25 per tie, free on board, at English ports. The ballast is of sand and gravel, and in places on the heavy grade an attempt at broken stone is found. The ballast is laid flush with the top of the tie. The results of experience have been most gratifying. The track is found to remain in better surface and line than when wooden ties are used, and certainly the track in best condition to-day is that portion where metal ties are laid. Practically it has been found that the track thus laid requires so much less work that section gangs on metal tie sections have been reduced about one-half. The Mexican Railway is therefore laying the steel ties as fast as possible, there being enough on hand to finish about 150 miles of road.

The following is the statement of Mr. George Foot, the general manager, furnished in 1887:

> Our experience with these ties, of which some 30,000 have been in the line since September, 1884, is so satisfactory in every respect, that we are now about to lay down 40,000 more, and our intention is to gradually relay the entire line with metallic sleepers. The type of tie we are about to lay down is about the same as that employed on the State Railways of India for both the 5 feet 6 inches and 1 meter gauges, but arranged for our gauge, which is 4 feet 8½ inches. The price of the new ties under contract in England is 4*s.* 4*d.* ($1.05) each, including steel keys, free on board in Cardiff, and their weight with keys 112 pounds each. The metallic ties in use here

for the last two years are almost of the same pattern, excepting the fastenings, which are much more complicated and expensive. The tie represents the latest improvements in steel sleepers suggested by experience on railways in India, where millions of them are employed, and I think that the tie in question leaves little to be desired either in general form, simplicity of fastenings, weights, or price. The metal is thickened where strength is most required, and the rail clips are formed from the solid plate, the rail being kept in place by a simple steel key which can be driven either on the inside or outside of the rail when increased width of gauge is required on sharp curves. So far we have no disadvantage to record, but many and very important advantages, which are as follows:

(1) No spikes are required.

(2) The rails are kept to gauge with almost mathematical accuracy and the result is that the oscillation of a train running at high speed over this track is reduced to a minimum, and is very marked when it runs on to a length laid with ordinary timber sleepers.

(3) The difference in the cost of maintenance is enormous, because a track once properly laid with these steel ties and well ballasted requires no permanent road gangs and can be maintained in good order by a traveling gang going over it once or twice a year.

This is our experience here, but it must be remembered that on this railway we have no frost or snow to contend with and very light traffic. In the United States these conditions would of course be altered, but I see no good reason why these ties should not bear frost well; they are extensively used in Germany, and I am not aware that frost has proved an objection to their use. From personal experience I can not say how metallic ties behave in cases where trains run off the line, as we very seldom on this line have such accidents, and have had none on the portions of track laid with them. In India the experience is that in a bad run-off a great number of ties are bent and injured, but that very few are so badly damaged as to be past repairs, and that, as a general rule, they are repaired in the shops and replaced in the line. I must add, however, that metal sleepers require a very solid and perfect road-bed, and a much larger quantity of ballast than timber ties. The Mexican Railway is laid throughout with 62-pound steel rails, except on the Cumber 4 per cent. incline, where we are now laying down 82-pound rails. Our metal ties are laid under the 62-pound rails, the number being 2,000 per mile, but we find that this number is not necessary, and in future we propose to lay only 1,850 per mile. I may say in conclusion, that in my opinion the steel tie is the tie of the future, and that our experience here points with their use to substantial economies in repairs and maintenance and at the same time to a very perfect track.

The following notes are from The Mexican Financier. The first one refers to the serious and disastrous floods of 1887:

The management of the Mexican Railway has reason to congratulate itself on the success which has attended the introduction of steel ties on its line. The recent washout, caused by the bursting of a water-spout on the track, afforded a test of the utility of metal ties than which nothing could have been more satisfactory. On the section where the spout burst there were both wooden and metal ties. The wooden ties were completely washed away and the track badly torn up, but on that portion having the steel ties the bursting spout was unable to do any harm to the track, the ties retaining their place and the line of rails remaining at their original level. General Manager Foot, who made a personal inspection of the washed track, could not find that the section having the metal ties had been sensibly damaged; only the gravel between the ties had been carried away, leaving them in their original place and preserving as has been said, the level of the track just as it was before tons of water had swept down upon it. The bursting spout carried much débris on the track and loaded an iron bridge with bowlders, some weighing fully 6 tons, in fact so heavy that they had to be blasted to accomplish their removal, and this fact will indicate the tremendous force of the waters and demonstrate convincingly the merits of the Rendel steel ties which kept the submerged track in such good order.

The road began using steel ties in 1884, and has now some 20,000 of them on its bed. So satisfactory has the experiment been that 40,000 more have been ordered from England for use this year, and it is proposed to put in from 40,000 to 50,000 per year hereafter. The "life" of a steel tie is considered as indefinite, but it may safely be set at from thirty to fifty years, the former being an American estimate by a competent metallurgist. The steel tie is now produced in England where the manufacture has been so extended as to make the product for 5*s.* apiece, or $1.25 gold, or very much cheaper than formerly. By chartering its own vessels the company can land its steel ties at a cost which permits their extensive use. It may be set down that the outside cost will not exceed $2 each, Mexican silver. The wooden ties which the steel ties are replacing on the Vera Cruz line range in price, according to the quality of wood, from 90 cents to $1.62, silver. The latter price is paid for the zapote tie, a very hard and durable wood. The best white-oak ties last from five to six years, the red oak about three years.—(1889).

The policy of the management has, for a long time past, been directed toward making the road-bed exceptionally solid, and a large amount of money has been invested in steel ties which have proven well suited to the requirements of the line, known to be one of the most difficult of maintenance in the world, on account of its tremendous gradients. The good results of this wise building up of the line will be seen when the competition of the Interoceanic Railway begins, for then it will be made evident that, by having got its road-bed into a condition where it can be kept in repair at a comparatively small expense, the line can sustain a sharp rivalry.—(1889).

MEXICAN CENTRAL RAILWAY.—In February, 1888, Mr. Max E. Schmidt, then chief engineer of the Tampico division, wrote me as follows:

> We have not yet used metal cross-ties on this line, but are considering the advisability of introducing them on our mountain division. In that case we will probably adopt the steel tie of the Indian State Railways lately introduced on the Vera Cruz Railway. This tie has the advantage of a most simple mode of fastening the rail to the tie, the rail being placed between two clips turned up from the bearing surface of the tie itself, only one wedge being required to hold each rail in place. Steel ties have two main advantages: (1) They last much longer than wooden ties; (2) they keep the track in perfect gauge. The question not yet settled is the kind of ballast which will keep the tie immovable in place.

SUMMARY OF METAL TRACK FOR SECTION 5.

Countries.	Bowls.	Cross-ties.	Total.
	Miles.	*Miles.*	*Miles.*
Argentine Republic	3, 350. 15	193. 41	3, 543. 56
Chili		1. 00	1. 00
Brazil	82. 46	3. 72	86. 18
Venezuela	23. 00	57. 25	80. 25
Costa Rica (probably experimental)			
Mexico		77. 00	77. 00
Total	3, 455. 61	332. 38	3, 787. 99

SECTION 6.—NORTH AMERICA.

UNITED STATES.

GENERAL REMARKS.—In this country very little practical attention has been paid by railway men to the use of metal track until within the last few years. The indifference displayed has been largely due to the increased first cost for metal and the apparently inexhaustible supply of timber. But with the steady improvement in the tracks of the principal lines and with the knowledge, as disseminated by the Forestry Division, of the actual condition of the timber resources there is a noticeable increase in the attention paid to this matter, and this will probably continue to increase. The metal track question, however, has been extensively considered by inventors, and much time, energy, and money have been spent in demonstrating, on paper, the positive efficiency of numerous new designs of track. The list of patents given with my preliminary report, in Bulletin No. 3, was surprisingly large, showing a total number of about two hundred and sixty patents from 1839 to 1889.* Very few of these patented tracks have been designed by railway men or men experienced in railway work, and the number of those which have practical merit is very small. Many of them are utterly impracticable, complicated, and costly, while others are carried to the opposite extreme of simplicity, with the result of sacrificing such efficiency as they might otherwise possess. The natural result of all this, combined with the large claims made from time to time in behalf of some of these impracticable systems, has been to render engineers, managers, and railway men generally somewhat doubtful as to the final solution of the metal track question. While some of the systems tried in actual service have not yet proved entirely satisfactory, it should be thoroughly understsood that no such system can be expected to give satisfactory results until it has been tested by trial and modified in accordance with experience obtained. Practical trial alone can show the actual results of any system of metal track.

The following remarks are taken from the report for 1888 of the railway commissioners of Connecticut:

> We have in former reports mentioned the experiments made in the use of metal ties, and we refer to the subject now not as one requiring legislative action, but simply as a matter of practical and scientific interest. The supply of wood has so far continued so abundant in this country that the first cost of ties has not very materially increased, but the average life of a tie has considerably decreased, both because of inferior quality and greater wear upon them. We are not aware that experiments with

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* The list of patents appended to this report contains 491 numbers.

metal ties of any account have been made in this country, but on the continent of Europe, where experiments began nearly twenty-five years ago, their use may be said to have passed the experimental stage, some companies having practically adopted this kind of tie and using them in all renewals. The most thorough experiments were made on the Netherlands State Railway, and the adoption there has been the most complete. In England, though used to some extent, they have not been at all generally adopted, as they do not seem to be well adapted to the double-headed rail so much used in in that country. The material found to be best adapted for this use is steel of a mild type, and the advantages claimed, apparently with reason, are such as to make it worth while for the managers of our principal roads to consider whether the adoption of this kind of tie would not be advantageous, even at the present price of wooden ties. The crowding outward of the spikes in wooden ties and the cutting of the spikes by the rail flanges on sharp curves constantly affects the gauge, and the cutting of the outer flange into the tie often seriously changes the position of the rail on wooden ties and requires constant watchfulness and respiking and readzing of old ties and the substitution of new ones. As traffic increases the loss of time thus occasioned in itself becomes a very serious item of expense. This is avoided by the use of metal ties, as the bolts do not cut like the spikes and the bolt-holes do not enlarge, neither do the ties wear or cut under the rail flange; so that the expense of maintenance is very much lessened, and instead of increasing as the road-bed gets settled it is said to decrease. The most approved form for the tie is like an inverted trough, and when the ends are closed there is very little lateral displacement of track, even on the sharpest curves. The first cost of metal ties and their fastenings is, of course, very much more than that of wooden ties and spikes, but their durability in itself, it is believed, far more than compensates for the additional cost.

NEW YORK CENTRAL AND HUDSON RIVER RAILWAY (See plate No. 27).—The chief engineer of this road, Mr. Walter Katté, having recognized the importance of the metal track question to the great trunk lines of railway, became desirous of obtaining some reliable data based upon experiments made under his own supervision. The company authorized an expenditure of $2,500 for the purpose of procuring such ties and testing them upon its own track. Various forms of ties used in foreign countries were examined, none of which, however, were considered to meet entirely and satisfactorily the conditions of American railway practice. The "Hartford" tie, with certain modifications to be made at his suggestion, seemed to Mr. Katté the best suited of any he had examined, and as it could be made in this country under his own observation as to manufacture, test of material, etc., he concluded it was the best one he could get, at least to start with, in investigating practically the question of metal ties. It is intended to conduct a close investigation of the comparative cost of maintenance, expenditures, renewals, etc., as compared with ordinary wooden ties. About eight hundred of the steel ties were purchased and were laid in double track on the main line. The company's standard system of track is used, consisting of good broken-stone ballast, with 80-pound flange rails, three-tie supported joints, and six-bolt angle-bar splices 40 inches long. The rails are laid to break joint. As stated in my preliminary report (Bulletin No. 3), it was expected to have these ties laid in April, 1889; owing to delays in manufacture, etc., they were not put in the track until November, 1889. They are laid for about a quarter of a mile on the main line, just south of Garrison's Station, Hudson River division. They are of two lengths, 8 feet and 8 feet 6 inches. They were at first laid in gravel ballast of mediocre quality, but this has been replaced with broken stone, in accordance with the company's approved form of track. The flanges of the angle-bars are notched to allow the clamps to bear on the rail flanges.

The following particulars are from a statement and drawings furnished in January, 1890, by Mr. Katté:

The ties were laid in November, 1889, on an experimental section of double track about a quarter of a mile long. The section is level and straight. The line has the heaviest kind of freight and passenger traffic. Passenger engines, with a weight of 36 tons, on four driving-wheels and a driving-wheel base of 6 feet, pass over these ties at speeds of 40 to 55 miles per hour. The ties have not been in use long enough for the expense of maintenance to be determined. Apparently, however, it is thus far no greater than with wooden ties. The arrangement for curves is the same as for tangents, any adjustment of gauge being effected by the fastenings. The rails weigh 80 pounds per yard and have supported joints. The reason for using these ties was the desire to secure economy over wooden ties and to obtain a superior attachment of the rails to the ties. The results have so far been quite satisfactory. There has been no trouble with maintenance nor with the rail-fastenings. No breakages have occurred. The attachment of the rails to the ties is much superior to the ordinary system of spiking. The wooden ties are of Southern yellow pine. They cost 55 cents each, delivered in New York, and have a life of from seven to ten years. The climate is variable, humid, with extremes of temperature. There is no record of the effects of the same on metal or wood.

I am of opinion that the rolled metal tie is essentially a requisite for first-class permanent way in this country. Having investigated the relative economy of metal and wooden tie systems for a term of fifty years, I am led to believe as the result thereof that upon the basis of 55 cents for a wooden tie and $3 for a steel tie, and under the conditions of traffic and maintenance expense existing on this line the relative economy is from 8 to 12 per cent. in favor of the metal system. The general advantages which I recognize in the metal system are: (1) Superior and more effective fastening of rail to tie. (2) Better hold of metal cross-tie with curved ends in the road-bed ballast, thereby preserving alignment both in straight line and curves much more effectively than with wooden ties. (3) Increased and effective resistance to tangential pressure on curves, with overturning tendency, and resistance to creeping of rails, especially on steep grades. (4) The clip and bolt fastening to the tie avoids the necessity of double-spiking the rail braces on curves. (5) Immunity from destruction of wooden ties by fire from coals dropped from locomotives and other causes. (6) The greater commercial value of the scrap material when worn out.

The ballast is about 24 inches deep; it consists of a 6-inch bottom course of rough quarry spawls, 4 to 6 inches diameter, and an 18-inch upper course of crushed rock 2 inches diameter. The ballast is brought up level with the tops of the ties. From the center of the rail to the outer edge of the ballast is about 6 feet 6 inches. The drawings show the rail joints spliced with plain splice-bars 22 inches long, with four bolts. Angle-bars are actually used, as already stated. Four arrangements of spacing of the ties are being tried; the rails are laid to break joint in all cases, with supported joints: (1) Thirteen lengths of 30-feet rails, with twelve ties to a rail length; the three-joint ties are spaced 18 inches, center to center, and the intermediate ties 3 feet. (2) Fourteen lengths of 30-feet rails, with twelve ties to a rail length; uniform spacing of 30 inches center to center. (3) Fourteen lengths of 30 feet rails with fourteen ties to a rail length; the three joint ties are spaced 18 inches, center to center, and the intermediate ties 2 feet $4\frac{13}{16}$ inches. (4) Fourteen lengths of 30-feet rails, with fourteen ties to a rail length; uniform spacing of 2 feet $1\frac{1}{16}$ inches, center to center. The close spacing of the ties at the rail joints is considered necessary for the existing severe conditions of traffic.

The cast-iron bowls designed in 1885 by Mr. John M. Toucey, general superintendent of the road, were intended for yard service and are still in use at the Grand Central station, New York City. (Description of the Hartford and Toucey ties will be found a few pages further on.)

CHICAGO AND WESTERN INDIANA RAILWAY (See plate No. 28).—About 1,000 feet of track near Chicago, Ill., have been laid with the "Standard" steel tie for experimental purposes, and up to the end of 1889 they had been in service about three months. It was then reported that they appeared to be satisfactory, but that it was too soon to express a decided opinion in regard to them. The traffic is about eighty trains per day; all in one direction. The locomotives weigh 96,000 pounds, and have a weight of 15,000 pounds on the driving-wheels. The track is as firm as could be expected for the open winter that has been experienced. It makes very easy riding and causes very little noise. The ballast is of light gravel. The ties are spaced $23\frac{1}{3}$ inches apart, center to center. They are 7 feet long and 3 inches deep; joint ties, 10 inches wide; intermediate ties, 7 inches wide. There had been no trouble with the rail fastenings, but a little rust had been noticed where the bolts come in contact with the clamp. The rail joints are square (or opposite), and are supported; they are spliced with plain splice bars weighing $18\frac{1}{2}$ pounds per pair; angle-bars could not be used as the flange would interfere with the rail clamp. The company which is introducing this tie claims that the clamp fastening will obviate the necessity for the use of splice bars and bolts, the clamps holding the rails firmly by the flange. Many railway men, however, consider that it is not sufficient to hold the rail by its base. In view of the fact that rails are not always vertical in the web, and are liable to bend, especially under heavy traffic, it may be found inadvisable to dispense generally with the use of splice-bars, which serve to keep the rail ends in line. Particulars of the "Standard" tie will be found a few pages further on.

The following is a letter written to the Standard Metal Tie and Construction Company of New York, in January, 1890, by Mr. J. W. Clarke, roadmaster of the Chicago and Western Indiana Railway Company and the Belt Railway Company of Chicago:

Answering your inquiry as to the condition of the Standard steel ties now in our track on main line, north of Seventy-first street, I beg to say that these ties were laid on the 1st of October, 1889, and, as you are aware, they were put in at the above location on south-bound track for the reason that at this point the ballast is very light gravel, which would make the test much more severe than if they had been put in at another location of the road. The traffic on this section is eighty regular trains in one direction every twenty-four hours; the heaviest engine weighs 96,000 pounds, with 15,000 pounds on each pair of drivers.

So far the ties have given perfect satisfaction, requiring but slight attention, and that only when first laid. There are no loose bolts, clips, or nuts, and so far there have been none. It would be impossible for me to estimate correctly at the present time the saving in maintenance, as the ties have not been in service long enough. I believe, however, that there will be a great saving in maintenance, as the only things to need attention are the bolts and clips, and so far they have shown no indication of weakness in any particular. There has been no upheaval of the ties where the ground is frozen, and from present indications I hardly believe that such will occur. The ties are in good line and surface, and hold the rails in an upright rigid position, so that the wear on the rail head seems to be more uniform and even than where wooden ties are used. I am free to say that the ties have so far surpassed all my expectations.

There seems to be no possibility of spreading of the rails. Should a rail break there would be less liability to accident, for the reason that the fastenings hold the rail absolutely firm and rigid. I believe that the saving in maintenance that will eventually be shown, and the absolutely safe, permanent way which these ties make, to say nothing of their greater life, will show greatly in their favor.

DELAWARE AND HUDSON RAILWAY.—Steel ties are to be tried on this road. An order for 1,500 "Standard" ties was given in April, 1890, to the Standard Metal Tie and Construction Company, of 15 Cortlandt street, New York, and they will be laid north of Ballston on what was originally a part of the old Saratoga and Schenectady Railroad. The ties are to be 7 feet long and 7 inches wide; they will be in gravel ballast and will be spaced 2 feet, 2 feet 6 inches, and perhaps 3 feet apart for experimental purposes. The rails weigh 67 pounds per yard and rest on blocks of compressed wood. The joint is of a new type; a channel-bar 4 inches deep is placed under the rail ends, and a clamp on each side takes hold of the rail flange and the bottom of the flange of the channel. Four bolts, with the Harvey grip-thread, pass through the clamps and channel-bar under the rail. No ordinary splice-bars are used, the rails being held by the flanges only. The joint ties are spaced 2 feet apart, and the channel-bar and clamps are as long as the distance between these ties. The order for the ties was given through Mr. H. G. Young, second vice-president of the road, and Mr. A. J. Swift, chief engineer. The Standard ties are in experimental use on the Chicago and Western Indiana Railway, and are described further on.

PENNSYLVANIA RAILWAY (See plate No. 29).—Mr. William H. Brown, chief engineer, stated in February, 1889, that the iron ties tried on this line had not been satisfactory. Four or five different kinds had been tried but there was not one that gave any satisfaction, and they had all been taken out with the exception of the steel ties obtained from the London and Northwestern Railway, England; and it was supposed that these also would be taken out in a year or two. In October, 1889, Mr. Brown stated that a few metal ties had been in service for about nine years, but that they had all been taken out of the main track, with the exception of small lots. They were made of channel iron, from designs prepared by the engineer, and cost $4 each. As will be noticed by the description given further on, the construction of these ties involved considerable shop-work. One bolt on each side of the track might, however, be dispensed with. Some of these ties were laid on the Filbert street extension in 1880, and in 1885 about 400 or 500 were laid on the 4½-degree curve in the West Philadelphia yard, where 134 fast passenger trains passed over them in 24 hours. They had no elasticity and were very hard to keep in line. It was concluded that as long as good oak ties could be procured at a price not exceeding $1 each, it would be cheaper to use wooden than iron ties. The price being paid for oak ties in October, 1889, was 65 cents per tie, delivered on the line of the road. In a letter published in 1886, Mr. Brown stated that the iron ties gave perfect satisfaction and were no more trouble to keep in line and surface than wooden ties, but in October, 1889, he stated as follows:

> In our experience a metal tie is not worth half as much as a wooden one, and as long as we can get first-class white-oak ties at our price of 65 to 75 cents each, it would be very foolish for us to use metal ties that cost $3 and $4.

This road has two sections of track laid with the standard metal track of the London and Northwestern Railway (See "England"), consisting of steel cross-ties with steel rails of bull-headed section, weighing 90 pounds per yard, secured in the chairs by steel keys. This track is said to be more easily kept in line than track on the company's own iron ties, in spite of the English ties having open ends. This is attributed to the greater stiffness of the rails. One of the sections of track is near Harrisburg, Pa., the other is on the New York division, west of the station at Menlo Park, N. J. On the latter location they are laid on the most southerly of the four tracks, which is the track for east-bound freight trains. There are about eight hundred ties in all, spaced 3 feet, center to center, giving ten ties to a rail length of 30 feet. The track is on tangents, one curve and one short bridge; on the bridge the ties are placed on wooden cross-ties having beveled edges. The rails are laid to break joint, and the joints are spliced by deep bars with four bolts. The ballast is of broken stone; and fine broken stone is filled in, covering the ties. This covering is not used on the other tracks, which are laid with wooden ties. I examined this section of track in November, 1889.

CHICAGO, SANTA FÉ AND CALIFORNIA RAILWAY (See plate No. 30).—On the Illinois division of this line the Taylor tie (described further on) has been in use on a few rail lengths for over two and one-half years. They are reported to have been laid in poor ballast, and to have carried heavy traffic.

Official reports made to me in February, 1890, speak unfavorably of these ties. There are twenty-two of them at Streator, Ill., in the yard west of Main street, between the crossings of the Wabash Railway and the Chicago and Alton Railway. They were laid in August, 1887, and are on a length of about 40 feet on a level and straight track. Mr. R. R. Coalman was the engineer in charge. There is a train every hour. The locomotives weigh 85,000 pounds. The bowls of the joint ties are 8 inches by 19 inches; those of the intermediate ties are 8 inches by 14 inches. They are of steel, five-eighths inch thick, and weigh 50 pounds. The joint and second ties are spaced 20 inches, center to center; the others are spaced 24 inches, center to center. The fastenings consist of lugs on the bowls and on the ends of the tie-bars as described further on. The expense of maintenance is said to be 50 per cent. more than with ordinary ties, and the durability is "not very good." The rails are of flange section, weighing 70 pounds per yard; the joints are supported, and are spliced by angle-bars. The ballast is of cinders and gravel, and does not behave well under the tie. The general results are not satisfactory. There is trouble with maintenance of track and with the rail attachments, but no trouble from breakages. In January, 1890, when the ties were examined for the purpose of this report, the track was found to be 2 inches lower than the other part of the track; it had been raised 3 inches above the level of the other ties, but would not stay up. The ties were hard to tamp and the gravel worked out from under them. From the experience with these ties it is thought that they will not last any longer than good wooden ties, while the cost for maintenance is much greater.

LONG ISLAND RAILWAY (See plate No. 30).—A few ties of the "International" type, described further on, were sent by the inventor for trial, and up to the end of 1889 had been in service for about two years. They were laid for a length of about 40 feet, and were spaced 2 feet apart, center to center. The rail joints are suspended. The track is ballasted with cinders, filled in level with the tops of the ties. The track is said to be not more firm than that with wooden ties, and its length is too short to enable its riding qualities to be determined. The ties are 8 feet long. The average amount of traffic is 100 trains per day. The heaviest locomotives weigh 146,050 pounds with a weight of 59,000 pounds on the driving-wheels. The number of ties is too small and time of trial too short for any definite conclusions to be drawn as to maintenance, but it is thought it would cost as much as, or more than, the track with wooden ties to keep in good line and surface, and for maintenance. The rail fastenings have given no particular trouble. Several ties have cracked under the rails. On the whole, the results are not considered to be very satisfactory, but, as already stated in the "general remarks," a few pages back, the metal tie question is quite in its infancy in this country, and ties which have not thus far met the requirements and conditions to be fulfilled may be improved in the light of actual experience so as to be ultimately efficient. These remarks apply also to the ties described in the previous paragraph.

BOSTON AND MAINE RAILWAY (See plate No. 30).—A few steel ties of the "International" type have been tried on this line. They were laid at Somerville, Mass., in July, 1885. Different patterns were used, most of them in two pieces, riveted together at the middle rib or web; others in one piece with riveted angle-pieces to which the rail clamps were bolted. They all had the top table crowned at the middle. Some had only half the width of each end closed; others had a part of the side at each end cut away. This was to facilitate tamping. I visited the track in September, 1889, but the ties had all been taken out (and piled near the line), as the notch in the rib was not wide enough for the flange of the new rails which are being put in. Some were cracked at the rail-seats. The section-master in charge of this section spoke well of the ties; he considered that there was but little more trouble in tamping, especially with the ties having a part of the sides cut away. The ties gave a bearing of 14 inches for the rail, and were spaced 28 inches, center to center.

MAINE CENTRAL RAILWAY—(See plate No. 30).—On this line also a few "International" ties have been tried, and have been in service since 1885. I examined them in September, 1889. There are only fifteen ties, or one rail length, and they are laid in the freight-yard at Portland, Me. They were put in at the request of the inventor. The ties have half of each end open. In a freight track, where a good deal of switching is carried on, the rib would be bad in case of derailment, as it might strip the trucks from a car which otherwise might have been got back on the rails without injury. As the rib would also be dangerous to brakemen in coupling cars, etc., being likely to trip them up, the space between the rails is filled in with gravel. The yard-master stated that these ties had not been touched since they were laid, which could not be said of any of the wooden ties during the same time.

DENVER AND RIO GRANDE RAILWAY.—A very limited trial of metal ties has been made on this road. In October, 1889, Mr. R. E. Briggs, chief engineer, stated that there had never been a trial made of a character to afford information of value. A few years ago a few iron ties (probably a dozen) were laid in the track near Denver, but were taken out after a short time, and no record of them has been kept. From another source I learn that the ties were probably of trough section with a wooden block under each rail, and that probably a larger number was tried than above noted.

PHILADELPHIA AND BALTIMORE CENTRAL RAILWAY.—On this line, which is now a part of the Philadelphia, Wilmington and Baltimore Railway, trials of the Travis iron ties were being made in 1879. The following is from the Railroad Gazette, New York, of March 28, 1879:

> At the meeting of the Engineers' Club of Philadelphia on March 15, 1879, C. E. Buzby exhibited a model of the Travis iron tie, which was then being tried on the Philadelphia and Baltimore Central Railway, near Lamokin. It dispensed with all spikes, bolts, nuts, or fish-plates, and drilling or punching rails. Each tie was recessed under the rails, and along the bottom of the recess wedge-shaped pieces were cast transversely. At the sides of each recess are creosoted blocks, which form a cushion and a fulcrum for two clamps, which grasp the flange and web of the rail above, bearing upon opposite faces of the wedge below. The weight of the train

forces the clamps upon the wedge, spreads them out at the bottom, and causes the upper part to grip the rails. The first cost was somewhat greater than that of the wooden ties, but it was said to offset this in durability.

In January, 1890, Mr. H. F. Kenney, general superintendent of the Philadelphia, Wilmington and Baltimore Railway, wrote me as follows:

> In 1878 one hundred iron cross-ties of the Travis pattern were placed in the track, on our Maryland division, and were removed after having been in use for a period of four years and seven months. The results obtained were not at all satisfactory, the expense of surfacing and lining amounting to considerably more than with wooden cross-ties. A number of these cross-ties, of a similar pattern, were laid on the Chester Creek branch, on our central division, during 1879. These ties, like those in use on the Maryland division, failed to give satisfactory results and were removed from the track after a period of about four years' service.

DELAWARE, LACKAWANNA AND WESTERN RAILWAY (See plate No. 30).—On this line six ties, of a type designed by Mr. Hicks, of New York, have been in use for some months in the yards at Hoboken, under heavy drilling and switching traffic. Mr. Neafie, the roadmaster, states that they behaved well; better, in fact, than had been expected. The tie as at present made is not considered suitable for main tracks, as the wooden blocks are liable to split, the grain being parallel with the rail. In dry weather, too, the wood would shrink and might become loose. The ties are in cinder ballast. (See "Hicks'" system.)

Mr. Neafie has designed a metal tie especially for use at road crossings. Two pieces of old rail with a chair secured at each end, form the tie. There is no intention of applying this plan to ordinary track, but it is intended especially for the crossings as above mentioned.

It is claimed that these experiments were not conclusive, and that with certain modifications the tie would prove successful. An improved form of tie of this type, designed to meet the objections experienced with the original Travis tie, has been invented by Mr. E. Brandwood, of Philadelphia, Pa. (See Brandwood Tie, page 289.)

TIES.

The Hartford Tie (See plate No. 27).—This is a rolled Bessemer-steel cross-tie, of inverted-trough section, with a channel or groove along the middle of the top table for the entire length of the tie. The dimensions are as follows: Length, 7 feet 6 inches to 8 feet 6 inches; width on top, 8 inches; width at bottom, 10¼ inches; depth, 2½ inches. The metal is three-eighths inch thick at the sides and five-sixteenths inch on top. The channel or groove is 2½ inches wide and five-eighths inch deep. The ends are closed by curving the whole tie to a depth of 5½ or 6 inches. The weight is 150 pounds, including the fastenings. The ties are treated with Dr. Angus Smith's asphaltum process, applied at a temperature of 300° Fah. The fastening for each rail consists of two clamps five-eighths inch thick; the clamps are wedge-shaped in plan and lie under the rail in the channel of the tie. At the broad end of each clamp is a hooked projection or lug, which holds the flange of the rail. A bent bolt, seven-eighths inch diameter, with its head at an angle of 53 degrees with the body, is used on each side of the rail; the head is on the under side of the top table of the tie, and the body passes up through the tie and clamp. The neck is oblong, $\frac{7}{8}$ by $1\frac{3}{16}$ inches. The nut screws down on the inclined face of the end of the clamp. At first the clamp had a hole for the bolt, but as now made it has a slot to receive the bolt;

ERRATUM.

In the copy of the Second Edition of Bulletin No. 4, of the Forestry Division, recently sent to you, the following paragraph should have been inserted above "Delaware, Lackawanna and Western Railway," following "four years' service," line 13, page 284.

It is claimed that these experiments were not conclusive, and that with certain modifications the tie would prove successful. An improved form of tie of this type, designed to meet the objections experienced with the original Travis tie, has been invented by Mr. E. Brandwood, of Philadelphia, Pa. (See Brandwood Tie, page 289).

by this means the clamps can be shifted, so that the track may be adjusted accurately to gauge, with any variation in the width or thickness of the rail flanges. The gauge can also be thus easily widened at curve or contracted at frogs and switches, and rails with worn heads may be shifted in to maintain a uniform gauge. The bolt being at an angle, a strong grip is secured. Lock-nuts are not used, but the bolts have the Harvey grip-thread, which in itself forms a nut-lock. Powerful wrenches must be used, as the security depends upon the upsetting of the threads within the nut. Under exceptionally severe conditions of traffic, however, nut locks may be used as an extra precaution. This is the fastening as improved in accordance with suggestions made by Mr. Walter Katté, chief engineer of the New York Central and Hudson River Railway, who is now conducting a careful trial of these ties, as already noted. The ties cost $3 each, including fastenings. They are manufactured by the Pennsylvania Steel Company, of Steelton, Pa., for the A. J. Hartford Steel Railway Tie Company, of Temple Court, New York city. Their life is estimated at fifty years.

Ties of this type, but flat on top, without the groove or channel, have been designed. The special object is to permit of shimming up the track, which becomes necessary with the disturbance of the ballast by frost in certain sections of the country. The impossibility of shimming has been an objection to metal ties, which has frequently been urged by practical track men.

The Standard Tie (See plate No. 28).—This is a steel cross-tie of channel section (⊔), stamped to shape from a plate. The intermediate or ordinary ties are 7 feet long, 7 inches wide over all, and 3¼ inches deep over all. They weigh 82 pounds each and cost $2.50. The joint ties (for supported rail joints) are 7 feet long, 10 inches wide, and 3¼ inches deep. They weigh about 105 pounds, and cost $3.50 each. The metal is three-eighths inch thick throughout. The bottom of the channel is cut loose from the sides at the middle portion of the tie, and the parts bent up at an angle, so as to offer resistance to lateral motion, the ends of the tie being open. The tie is intended to be filled with ballast. Each rail rests upon a block of preserved and compressed wood placed with the grain vertical. It is expected that this block will give a firm support to the rail, will not be cut by the flange, and will be durable. Each block is 4½ inches wide by 6½ inches long (or 9½ inches for joint ties) and 2⅝ inches deep. The rail rests only on the block, the sides of the tie being cut away to a depth of one-half inch for the width of the rail flange. The fastenings consist of Z-shaped clamps, the upper rib holding the rail flange, while two projections forming the lower rib pass through holes in the bottom of the tie and take a bearing against the under side of the bottom. The upright web is nearly vertical, but curved so as to grip the wooden block. The clamps are as long as the inside width of the tie. At intermediate ties the clamps are screwed up to a bearing on the rail flange by a bolt three-fourths inch diameter, passing horizontally under the rail through both clamps and the wooden block. The center of the bolt is one-half inch below the top of the block. At joint ties two bolts are used. It is claimed that this fastening will obviate the necessity for the use of splice-bars and bolts, but as already noted, in view of the fact that rails are not always vertical in the web and would have a tendency to be bent at unsupported ends, it may be that the use of splice-bars will be found desirable, especially for track with heavy traffic. These ties are said to be especially adapted for roads with a narrow width of ballast, as the resistance to lateral motion is at the middle instead of at the ends of the tie. They are also claimed to be suitable for bridge floors and elevated railways. In the latter case, the bottom of the channel would be cut away entirely between the wooden blocks, so as to offer as little obstruction to light as possible; they would in themselves form the cross-bracing of the structure. The ties are manufactured at the Homestead Steel Works of Carnegie, Phipps & Co., at Homestead, Pa. They are stamped from steel plates by a hydraulic press designed by Mr. Aiken, of Pittsburgh, and built by the Scaife Foundry and Machine Company of Pittsburgh. They are being introduced by the Standard Steel Tie and Construction Company, of 15 Cortlandt street, New York City. They are being given a trial on the Chicago and Western Indiana and on the Delaware and Hudson Railways.

The Pennsylvania Railway Tie (See plate No. 29).—The channel tie designed by the engineer of the Pennsylvania Railway consists of an ordinary channel-iron (⊓), 8 feet 6 inches long, 7 inches wide, 2¼ inches deep, weighing 13½ pounds per foot. Each end is closed by an angle-iron 3½ inches by 5 inches, 7 inches long, weighing 7 pounds per foot. The shorter leg rests on the top table of the tie and is secured by two rivets. A piece of angle-iron 3 inches by 3 inches, 5½ inches long, weighing 6 pounds per foot, is also riveted inside of the channel just under the flange of the rail. The fastenings for each rail consist of a riveted brace on the outer side and a bolted clamp on the inner side. The brace on the outer side is a piece of angle-bar 7 inches long, secured to the tie by the two rivets which hold the angle-iron in the interior of the tie; this angle-bar or brace bears on the flange and under side of the head of the rail. The clamp on the inner side is a flat piece of iron 7 inches long, secured by two bolts; one bolt may be dispensed with in some cases. This clamp bears on the tie and flange of the rail.

The Toucey Tie (See plate No. 29).—This tie was designed by Mr. John Toucey, general superintendent of the New York Central and Hudson River Railway, expressly for laying in the Grand Central Station, New York City, where it was desired to pave. Each tie consists of a pair of cast-iron "bowls" of **H**-section, with outward, flaring sides. The bowls are connected by a tie-rod five-eighths inch diameter, the ends of which are bent down at right angles to fit into a hold in the middle web, the rod passing through the side of the bowl. The bowls are 18 inches long, 9¾ inches wide on top, 16½ inches wide at the bottom, and $8\frac{5}{16}$ inches deep. The thickness is from one-half to 1 inch. The upper part of the bowl is fitted with an oak block, to which the rail is secured by a pair of Bush interlocking bolts. The ties are laid 3 feet apart, center to center of tie-rods, giving 18 inches clear between the bowls. The weight of each bowl is about 100 pounds. The track was laid in 1885, and no breakages have occurred. There is a distance of about 3,000 feet laid with these ties. They are economical in that the track has not to be dug up and disturbed for renewals of ties. The wooden block is not vulcanized, creosoted, or otherwise treated; but it is considered that Georgia pine would last a long while, as it is away from dampness. The ties were also laid at the same time for several rail lengths at the entrance of the yard. Mr. Toucey stated in January, 1890, that these also are still in service. There have been no renewals or breakages.

The International Tie (See plate No. 30).—This is a rolled-steel tie, the cross section of which resembles a printer's "brace" (⏞). Originally it was made in two pieces riveted together at the upper flanges, but it is now made in one piece. Some of the earlier ties were in one piece, but had not the upper flange, a short piece of angle-iron being riveted at each side of each rail seat; the rail clamps were bolted to these angle pieces. To facilitate tamping, half of each end was left open or a piece of the side cut away at each end. As now made, however, the ends are open, and a transverse plate inside the tie, nearly under the rail seat, is secured by a rivet to each side. The usual dimensions are now as follows: Length, 8 feet; width, 10 inches; side flanges, 3 to 3½ inches deep; middle flange, 2 inches high. The thickness is from three-sixteenths inch at the bottom of the side flanges to three-eighths inch on top. At first the top table was slightly curved at the middle, but it is now made horizontal for its entire width. The middle flange is cut away in two places to admit the rail flanges. The weight of the tie is about 100 pounds. The price is about $1.50 to $2.50, according to length, etc. The fastenings consist of flat wrought-iron clamps bolted to the middle flange of the tie, one on each side of each rail. These clamps have projections which bear upon the flange of the rail, and these projections are so made as to give four different clearance heights between the tie and the clamp; this allows for rails with flanges of different thickness, and also for some amount of shimming. Some of these ties have been tried, as already noted, on the Long Island

Railway, Boston and Maine Railway, and Maine Central Railway. They are manufactured by the Cambria Iron Company, of Johnstown, Pa., for the International Railway Tie Company (of which the inventor of the tie, Mr. Higley, is treasurer), 45 Broadway, New York City.

The Taylor Tie (See plate No. 30).—This is an iron or steel cross-tie on the "bowl" system, each tie consisting of a separate piece under each rail, connected by a third piece forming a tie-bar. The bowls or rail-bearers are of inverted-trough section, placed lengthwise of the rail, and having a vertical transverse slot through which the deep flat tie-bar passes. At rail joints (supported joints) the rail-bearers are of extra length and two tie-bars are used, one to each rail end. With this system, as with the Standard system, the use of splice bars and bolts is intended to be avoided. The inner side of the rail flange is held by lugs stamped up from the metal of the top table of the bowl; the outer side is held by the hooked end of the tie-bar. No bolts or other loose parts are used. The rail-bearers are of sheet steel 14 inches long, 9 inches wide, 7 inches deep, five-sixteenths inch thick. The tie-bar is 6 feet long and one-half inch thick. The weight of the tie complete is about 90 pounds. With ballast that is fine or of poor quality it is proposed to use a tie-bar of ⊥ section (as shown on plate No. 30 (instead of the flat bar; the ⊥ bar would be 3 inches by 3 inches, vertical web three-eighths inch thick, horizontal flange five-sixteenths inch thick. The object is to give additional bearing surface. These ties (with flat bars) have been tried on the Chicago, Santa Fé and California Railway, as already noted. The inventor is Mr. E. L. Taylor, of 682 Brooklyn street, Philadelphia, Pa. He stated in January, 1890, that he had received several inquiries from foreign countries, and hoped soon to make arrangements for manufacture.

The Hicks Tie (See plate No. 30).—The ties already noted as being tried on the Delaware, Lackawanna and Western Railway are composed each of two angle-irons, so placed as to form an inverted channel. At each end two angle-pieces are riveted across the top of the tie; between these two pieces rests the oak block to which the rail is secured by spikes. The angle-pieces are not as high as the block, and as the latter has the grain parallel with the rail, it is liable to be cut by the rail and to be split by the spikes. The block is also liable to become loose in dry weather. The tie weighs about 100 pounds. Mr. Neafie, the road-master, suggests that it would be an improvement to make the angle-pieces as high as the wooden block, with the upper edges bent over. The block would be driven to a tight fit and would not be liable to be split. The ties are spaced 15 inches apart in the clear, or 27 inches center to center. Mr. Hicks proposes several modifications of the tie as now in use. One plan is to have the wooden blocks only 4 inches thick and long enough to reach from tie to tie, forming a continuous support for the rail, and the ends of the adjacent wooden blocks being on the ties. With this form of track an improved clamp fastening of simple form would be used instead of a spike. Another system designed by the same inventor consists of longitudinals carrying cross-ties, which are placed diagonally instead of at right angles to the rails. The ties are of channel section, with a wooden block under each rail. The object of placing the tie diagonally is to increase the length of bearing of the rails on the blocks. The cross-tie was invented by the late Capt. H. O. Cook, and has been modified and improved by the present owner, Mr. James M. Hicks, 19 Park Place, New York City.

The Durand Tie.—This tie is of inverted-trough section, somewhat resembling the "Post" tie (See "Holland"). It is narrow and deep at the middle. Lengthwise corrugations on the top table of the tie at the railseat are intended to give additional strength; vertical corrugations may also be made in the sides. The width of the railseat is 10 inches on top and 12 inches at the bottom. The thickness may be either three-sixteenths inch, giving a weight of 65 pounds per tie, or five-sixteenths inch, giving a weight of 100 pounds per tie. The cost is claimed to be $1 or $1.35, respectively. The ends are open, but can be closed by a special cap, which is to be put on after the tie is laid, and which can be removed to permit access to the bolts, etc. Experience has shown the advantages of closed ends for ties, and the proposed movable ends are not likely to be introduced. The fastenings consist of four bolts, with the heads welded to the under side of the top table of the tie. The nut-lock consists of a washer of soft metal; an indentation fits into a recess in the tie, preventing the washer from turning, and when the nut is screwed down one side of the washer is turned up against it. Various other fastenings are also proposed by the inventor in connection with his ties. It is proposed to roll old rails into sheets, from which the tie would be stamped by special machinery; any special arrangement of tie for curves, switches, etc., would be effected by interchangeable pieces in the machinery. The plant for rolling and stamping is estimated to cost $5,000, and the cost of manufacture is estimated at 30 cents per tie. The ties have been tried on a private trial line in the French Alps. The inventor is A. Durand, of Alexandria, Va., and Atlantic Building, Washington, D. C. (Patent No. 386,389; July 17, 1888.)

The Maloney Tie.—This is a cross-tie of cruciform section, the upper vertical flange being cut away in two places to allow the rail to rest on the horizontal web. The dimensions are as follows: Length, 6 feet 6 inches; width, 9 inches; top and bottom flanges each 1½ inches high. The thickness is one-fourth inch, increased to one-half inch at the rail seats. The rails are fastened by flat clamps, which are bolted to the top flange of the tie. The ties are to be rolled, the cutting for the rails and holes for bolts being made during the operation, so as to turn out a finished tie from the rolls. The four clamps for each tie weigh about 3 pounds, and the fastening of the rail is claimed to be very efficient. This tie was invented by Mr. M. Maloney, of Ironton, Ohio. He reported in January, 1890, that he was negotiating for its manufacture, and hoped to have it in service during the present year. (Patent No. 395,447; January 1, 1889.)

The Flower-Heller Tie.—This is a cross-tie in the form of a hollow box of rectangular section, with a wooden block inside under each rail. The top of the box is cut away to allow the rail flange to rest on the wooden block, and the rail is spiked to this block as to a wooden tie. For curves the tie is made shallower at the middle than at the ends, so as to form shoulders to resist lateral shifting in the ballast. The patents for these ties are owned by the American Metallic Railway Tie Company, 230 South Fourth street, Philadelphia, Pa. (Patents Nos. 386,119, July 17, 1888, and 370192, September 20, 1887.)

Phœnix Iron Works.—In June, 1889, Mr. Amory Coffin stated that metal ties were being used on all the new track being built around the works. There are several miles of narrow-gauge track, and as fast as the wooden ties give out they are renewed with metal. Channel-bars are used 6, 8, or 9 inches wide; of ordinary weight per yard, say 40 to 60 pounds.

The Price system.—This system consists of a longitudinal under each rail, made of a strip of steel bent or corrugated to form a series of troughs, open alternately at top and bottom. The sides of the troughs are flaring, the open parts being widest. The strip has a rib on each edge. The rails are secured by bolted clamps. The length of each stringer or longitudinal is about 30 feet. Light steel cross-ties are placed at intervals. The ballast is intended to be filled in to the top of the longitudinal. This system is owned by Mr. James M. Price, 1719 North Eighteenth street, Philadelphia, Pa.

The Hoffmeier system.—This system consists of cross-ties with arms at each end. The arms of adjacent ties dovetail together, forming a continuous stringer or longitudinal under each rail. The ties and longitudinals may be of various sections, and various forms of fastenings may be used. The inventor is Mr. A. K. Hoffmeier, of Lancaster, Pa.

The Holland system.—This consists of round or elliptical castings, with a dome-shaped diaphragm in each. The space above the diaphragm is filled with concrete or asphalt. The castings are not placed opposite one another in the track, but are staggered. They are connected by tie-bars. The system is the invention of Mr.

Robert M. Holland, of Philadelphia, who also has a patent on a cross-tie. (Patent No. 66,711; July 16, 1867.)

The Schofield Tie (See plate No. 30).—This cross-tie is of iron or steel, of deep inverted-trough section, with horizontal flanges on the bottom edges. Each rail is fastened by two clamps three-eighths inch by 2¼ inches, fastened by two five-eighth-inch bolts each. The tie is 5 feet 6 inches long, one-fourth inch thick, and weighs 50 pounds. It is estimated to have a life of fifty years and to be worth 50 cents when worn out. It is proposed to use three iron ties to a rail length of 30 feet, replacing three wooden ties, in order to increase the safety of ordinary track at small expense. It is reported that they are to be used in some special places on the Lookout Mountain Railway, near Chattanooga, Tenn. These ties are being manufactured by the Schofield Metal Cross-Tie Company, of Chattanooga, Tenn. (Patent No. 230,826; August 3, 1880.)

The Brandwood Tie.—This is a cross-tie of iron or steel with a section at its middle part of the form of a cross + and with the ends turned down. At each end of the tie is formed a hollow "box" deeper than the other portions of the tie, and the horizontal part of the tie is widened at the ends to form a plate around each box and to give ample bearing on the ballast. The bottom of the box is closed and has a rib of ∧ section under the rail. Each rail is carried on two clamps, the top of which is of ⊏ shape to hold the rail flange, and has a long lower leg of wedge form which fits into the box. The rib in the bottom of the box forces the lower legs of the clamps apart, causing the upper part to grip the rail tightly, especially when the weight of a train comes upon the rails. Wooden blocks are placed between the backs of the wedges and the sides of the box. At rail joints the upper part of the clamps is made of extra length, to give a good hold on the rail ends. No splice bars or bolts are used. The "box" is rather wider at the middle than at the sides, so that in renewals the clamps may be easily knocked loose from the sides of the box and withdrawn, thus obviating one of the defects said to exist with the Travis tie, that the clamps became wedged so tightly in the boxes that they could not be removed. This tie was designed as an improvement on the Travis tie. (See p. 283 and patent No. 206,647) by Mr. E. Braudwood, of Philadelphia, Pa., and patented December 9, 1890. (No. 442,416.)

SOUTHERN PACIFIC RAILWAY.—It is reported that trials of metal track are likely to be instituted on the Southern Pacific system.

LOOKOUT MOUNTAIN RAILWAY.—On this standard-gauge road up Lookout Mountain, near Chattanooga, Tenn., some metal ties are to be tried in special places. (See "Scofield" tie.)

CANADA.

Metal track has not been introduced, and in fact has probably never been considered with a view to its introduction or a practical trial. A prominent engineer, Mr. Thomas C. Keefer, writes as follows:

> I do not believe metal ties have been used in Canada. We have not even creosoted ties yet. With white oak ties at 50 cents, and tamarack and cedar at 20 cents, our railways, always living from hand to month, have never thought of anything else.

TABULAR SUMMARY OF METAL TRACK.

The following is a table giving a summary of the figures presented in the first parts of the report, showing that of the total length of railways in the world (exclusive of the United States and Canada) about 13.21 per cent. of the mileage is laid with metal track. The figures of the totals given can only be approximate, in consequence of omissions, incomplete data, and lack of figures brought up to the same recent date. The totals are, in all probability, considerably below the actual mileage, as shown by the figures for Germany and Switzerland. In the latter case the total compiled from data relating to the several railways, as given in my report, is nearly 100 miles below the actual total officially reported. It must also be borne in mind that the use of metal track is being continually extended.

Section 1.—Europe.

Countries.	Longitudinals.	Bowls and plates.	Cross-ties.	Total metal track.	Total track.
	Miles.	*Miles.*	*Miles.*	*Miles.*	*Miles.*
Great Britain			70. 00	70. 00	20, 000
France			52. 12	52. 12	21, 700
Holland	8. 06		321. 36	329. 42	3, 216
Belgium			115. 50	115. 50	3, 544
Germany*	3, 562. 52		5, 224. 12	8, 786. 64	25, 144
Austria and Hungary	66. 56		56. 37	122. 93	14, 942
Switzerland	. 25		303. 98	*397. 40	1, 810
Spain		251. 68	7. 10	258. 78	5, 772
Portugal			. 02	. 02	1, 120
Italy					7, 292
Sweden and Norway			. 50	. 50	5, 544
Denmark			18. 10	18. 10	1, 248
Russia					17, 682
Turkey			70. 68	70. 68	865
Roumania					1, 491
Servia					321
Greece					380
Totals of Europe	3, 637. 39	251. 68	6, 239. 85	10, 222. 09	132, 071

*Official statement of totals.

Section 2.—Africa.

Countries.	Bowls and plates.	Cross-ties.	Total metal track.	Total track.
	Miles	*Miles.*	*Miles.*	*Miles.*
Egypt	851. 75	35. 25	887. 00	1, 228
Algeria		120. 00	120. 00	1, 538
Tunis				
Abyssinia		14. 25	14. 25	14
Portuguese Territory (South Africa)		47. 75	47. 75	56
Natal				217
Cape Colony	80. 00	36. 50	116. 50	1, 736
South African Republic (Transvaal)		40. 50	40. 50	45
Reunion	62. 00		62. 00	78
Senegal		2. 50	2. 50	290
Mauritius				
Totals for Africa	993. 75	296. 75	1, 290. 50	5, 202

Section 3.—Australasia.

Countries.	Cross-ties.	Total metal track.	Total track.
	Miles.	*Miles.*	*Miles.*
South Australia	146	146	1,824
Queensland	40	40	2,103
New South Wales			2,168
Victoria			2,107
West Australia			160
New Zealand			1,843
Tasmania			375
Totals for Australasia	186	186	10,640

Section 4.—Asia.

Countries.	Bowls and plates.	Cross-ties.	Total metal track.	Total track.
	Miles.	*Miles.*	*Miles.*	*Miles.*
British India	5,312.25	3,912.25	9,224.50	15,245
Ceylon				182
Sumatra		90.00	90.00	90
Java and Dutch Possessions				720
Malay States				31
China				85
Japan				896
Asia Minor				372
Asiatic Russia				960
Cochin China				525
Totals for Asia	5,312.25	4,002.25	9,314.50	19,106

Section 5.—South America, Central America, and Mexico.

Countries.	Bowls and plates.	Cross-ties.	Total metal track.	Total track.
	Miles.	*Miles.*	*Miles.*	*Miles.*
Argentine Republic	3,350.15	193.41	3,543.56	4,650
Paraguay				90
Uruguay				345
Chili		1.00	1.00	1,650
Peru				837
Bolivia				43
Brazil	82.46	3.72	86.18	6,070
Ecuador				94
British Guiana				22
Venezuela	23.00	57.25	80.25	182
United States of Colombia				164
San Salvador				25
Costa Rica				115
Nicaragua				32
Guatemala				105
Honduras				37
Mexico		77.00	77.00	5,000
Totals	3,455.61	332.38	3,787.99	19,461

Section 6.—North America.

Countries.	Cross-ties.	Total metal track.	Total track.
	Miles.	*Miles.*	*Miles.*
United States	2.00	2.00	161,000
Canada			13,165
Totals of North America	2.00	2.00	174,165

Summary of totals.

Section.	Longitudinals.	Bowls and plates.	Cross-ties.	Total metal track.
	Miles.	*Miles.*	*Miles.*	*Miles.*
No. 1	3,637.39	251.68	6,239.85	10,222.09
No. 2	....	993.75	296.75	1,290.50
No. 3	....	....	186.00	186.00
No. 4	....	5,312.25	4,002.25	9,314.50
No. 5	....	3,455.61	332.38	3,787.99
No. 6	....	....	2.00	2.00
Total	3,637.39	10,013.29	11,059.23	24,803.08

NOTE.—The use of longitudinals is being abandoned. The bowls and plates are mainly in service in hot countries, with special conditions of traffic, as in India and South America. The cross-ties are used under conditions of climate, traffic, etc., most nearly according to the conditions obtaining in this country.

Percentage of metal track mileage.

	Total metal track.	Total track.	Percentage of metal track.
Section:	*Miles.*	*Miles.*	
No. 1	10,222.09	132,071	7.74
No. 2	1,290.50	5,202	24.80
No. 3	186.00	10,640	1.75
No. 4	9,314.50	19,106	48.75
No. 5	3,787.99	19,461	19.46
No. 6	2.00	174,165	....
West Indies	....	1,241	....
Total	24,803.08	361,886	6.85

Total mileage of railway with metal track	miles..	24,800
Total mileage of railways of the world (exclusive of United States and Canada)	miles..	187.721
Percentage of railway with metal track (exclusive of United States and Canada)	per cent..	13.21

PART II.

GENERAL REVIEW OF THE METAL TRACK QUESTION.

General Remarks.—In view of the information and statistics presented in this report, there can be no doubt that the use of metal track for railways has reached a stage beyond that of mere experiment, and that satisfactory results may be obtained with such track under certain conditions. Experience (under various conditions) has conclusively demonstrated the fact of the practicability of employing metal as a substitute for wood, for supporting the rails of railways. Not only has the practicability of using such track been shown, but also its advantages in economy, efficiency, and safety. That the experimental stage has been passed is shown by the extent to which this kind of track is in use, and its steadily increasing introduction. It remains now for us to profit by the experience already on record, making use of the improvements, modifications, and warnings suggested thereby in our actual practice. The main advantages presented by a good system of metal track are as follows: (1) Reduced expenses for maintenance and renewals, owing to the solid construction and the greater durability of the parts; (2) a better class of track, owing to improved fastenings, etc., and the fact that the road-bed is not torn up (as with wooden ties) for frequent renewals, so that it gives the best road with the least amount of work for maintenance; (3) increased safety for traffic, owing to the superiority of the fastenings over those used with wooden ties. Metal tie-plates and improved fastenings are being introduced in this country and abroad, to increase the efficiency of track on wooden ties, but the standard track of the future, for main lines with heavy traffic at least, will probably be laid with metal ties. It has been pointed out that the use of metal ties would have a beneficial effect on the iron trade, as the ties (except, perhaps, some lots imported for experiment) would be manufactured in this country.

In nearly all the principal countries of the world, and in many of the smaller countries, experiments have been made on a sufficiently large scale to enable reliable conclusions to be drawn as to the merits and demerits of the numerous systems of track which have been experimented with. It may be noted as of special significance that in Holland, a country without home manufacture of metal ties, but possessing ample resources of native and foreign timber at cheap rates, all the railway companies have used metal ties for a number of years, and that without pressure from the Government; the companies having considered this step to be in their own interest. Mr. Bricka, in his report to the minister of public works, France, in 1885, stated that the progress in this direction had been such that already some railways in Germany, Holland, and Switzerland had decided to abandon the use of wooden ties. In connection with the favorable opinions expressed by engineers in these countries, it is to be considered that in Switzerland and some parts of Germany where metal ties are used there are no iron or steel works, and, therefore, the fostering of a local industry had no influence on the opinions expressed, while Switzerland especially has plenty of timber. Mr. Post, in a paper written in 1885, stated that if, in comparing the costs of different systems of track, account was taken in each case of the different details (first cost, transportation, laying, maintenance, renewals, interest, selling price of old material, etc.) it would be seen that there are few countries where the exclusive use of wood for ties is really economical in the broad meaning of the word. This is specially evident as to hot countries where insects and atmospheric influences effect a rapid destruction of wooden ties.

In this country, railway men are very generally indifferent to this matter, or are waiting for a perfect tie to be brought to them. Among the reasons for this indifference has been the apparent abundance of our timber resources. But attention has now been drawn, especially by the Department of Agriculture, to the great destruction of these resources and the serious results of the denudation of large tracts of forest land. Other reasons have been the greater first cost of metal ties and the need of cheapness in railway construction. These considerations have some weight still, but on main lines, with heavy traffic, economical construction has become the main consideration rather than cheap construction.

A few practical experiments with different forms of cross-ties have been made and are now in progress. Other trials have also been made from time to time with a small number of ties, but these experiments are on too limited a scale to allow any definite conclusions and are generally conducted without much regard to practical results. If a metal tie could be designed and constructed that would meet at once all the requirements and answer all the objections, it would have a fair chance of being adopted. But it must be remembered that engineering is to a great extent the science of development. As the metal rail has been developed from the wooden rail, so has the metal tie been developed from the wooden tie. These developments have been by "trial and error," and it is practically an impossibility for a metal tie to be devised at once that will be successful in every way.

The ties that are now used with success in other countries are modifications and improvements of those first tried, and thus by degrees a really efficient tie has been obtained. In this country there have been discussed in the technical press various claims made by inventors for forms of ties existing only on paper or in miniature. It is probable that few of the ties designed and patented here have much real merit, as so many are invented by persons unacquainted with the requirements to be met or the conditions to be considered. Of the few that possess merit it may be said with reasonable certainty that actual trial will result in considerable modifications being made of the original design. Such trial may show that an apparently poor type of tie may be made valuable by some modifications, or that a tie of apparently good type is a failure in practice.

Among the requirements for a successful tie may be enumerated the following: (1) Heavy enough to hold the rails down well and make a firm track; (2) light enough to be of reasonable cost; (3) metal enough to stand wear and tear and give ample strength; (4) easy of manufacture, and requiring a minimum of shop-work; (5) not liable to lateral motion in the ballast; (6) easy to be laid, removed, or ballasted; (7) fastenings simple and efficient, with as few parts as possible, capable of adjustment for widening the gauge at curves etc.; (8) price such as to enable an actual ultimate economy to be shown to the engineers and financial officers; (9) proper quality of metal to sustain shocks without injury; (10) elasticity enough to give an easy-riding track. The following is a partial summary of the conclusions of the report made by Mr. Bricka in 1885:

(1) The ties should be of mild steel, to the exclusion of wrought iron.

(2) Ties of the original Vautherin type may be employed for sand and fine gravel ballast, but for coarse gravel or broken stone they should be without the bottom flanges. The Post and Berg-and-Mark ties are the best modifications of this type.

(3) They should be at least 8.2 feet long and 8.8 or 9.2 inches wide. The ends should be closed, but the use of extra cross-pieces inside is not necessary.

(4) The thickness should not be less than .28 or .32-inch, and should be at least .40 inch under the rail; it may be reenforced by a longitudal rib under the top table, or, better, by the Post system of rolling the rail-seat of extra thickness. The extra thickness must not involve unreasonable expense. The ties are rolled and punched.

(5) For flange rails the inward inclination is best given by an extra thickness of metal at the rail-seats; the use of tie-plates is considered preferable to bending the tie at the rail-seats.

(6) The weight should not be less than 110 pounds, but it has been proposed to reduce it below this reasonable minimum. A weight of about 121 or 132 pounds, or even more, is preferable for main lines.

(7) The best systems of fastenings for flange rails are the Ruppel system, used on the Prussian State Railways, and the Heindl system, of the Austrian State Railways; nearly all the bolt systems have given good results.

(8) The use of metal ties does away with use of the chairs for double-headed rails, and the combination of flange rails on these ties is simpler and less expensive.

(9) The price of the ties should not exceed $32 to $34 per ton, and that of the small material $50 to $70 per ton. (These prices are for France, 1885.)

(10) The life of metal ties is at least thirty years, or double that of oak ties. It can be shown that the use of steel ties weighing 121 to 132 pounds is not more expensive than oak ties when the latter cost $1.10 each and the former $32 per ton.

(11) The track on metal ties is as stable as but no harder than that on wooden ties, and it behaves better in case of derailment. When the track is established in good condition the labor of maintenance does not cost more than with track on wooden ties; it is probably more economical.

(12) The ties may be laid in ballast of any permeable material. A good splicing of the rail-joints is necessary with this form of track.

Mr. Bricka considered that engineers should make themselves thoroughly acquainted with results already obtained before introducing metal track for themselves. For careful comparisons of maintenance expenses he suggested trial sections of 6 or 9 miles, with varying conditions of alignment, profile, ballast, etc.; the expense of such trials would be small in comparison with the end to be attained.

Elasticity is necessary to make an easy-riding track and prevent any additional wear of the rolling-stock. Ties of polygonal or trough section, such as those of the Post and Vautherin types, are said to be especially elastic. The track on metal ties on the Central Railway of Switzerland is said to be even more elastic than that on wooden ties. It has been stated that a metal track would be too severe on the rolling-stock and too rigid for rapid traffic, but experience does not support this statement. In England trains run at a speed of nearly 60 miles an hour on metal track; on the European continent the speed varies from 37 to 45 miles per hour.

Rust is only experienced to a comparatively limited extent with wrought-iron ties and hardly at all with mild steel. It is mainly produced, as with rails, in damp tunnels or in cinder ballast, owing to the sulphuric acid and carbonic acid in the smoke and ashes. Wearing at the rail-seats, and longitudinal cracks at the same place, are not experienced with mild steel as with iron. The greatest probable trouble is from the wear of the holes for the fastenings, but this may be reduced to a minimum by proper construction.

Simplicity in design, manufacture, fastenings, and the arrangement of parts is especially to be aimed at, with due regard to practical requirements for strength, etc.; and the simplest system designed with such regard will probably give the best results in economy and efficiency. In some systems, however, this principle of simplicity has been carried too far, allowing no loose parts at all; the rails are either held by tie-bars with hooked ends or are sprung into place between fixed lugs or the ties are laid diagonally to let the rail fit onto its seat and are then shifted to their proper position, bringing the lugs to overlap the rail flange. Such methods may do for very light rails, but are hardly adapted for heavy traffic. With some forms of track special ties are required at curves; this is a very serious objection, as it not only increases the shop-work and expenses, but also makes more work and is likely to cause continual trouble in track-laying. All the ties, except those at frogs and switches, should be of precisely the same size and form, and adjustment of the gauge should be effected by means of the fastenings of the rails. In some European countries this question of simplicity appears to be a very secondary consideration, and there is a growing tendency towards the greater complication of the track by various forms of tie-plates, clamps, etc. The steel cross-ties of the Indian State Railway and the local railways of Belgium, however, make a track which is very simple in construction and which has shown its efficiency in actual service.

Metal ties will have a much longer life than wooden ties, and the old material will have a considerable market value. The actual life of metal ties has not been determined, as the older forms were not adapted to the conditions of modern traffic and rolling stock, and the newer forms have, as a rule, only been in service from five to ten years. Some of the older ties have been in service for fifteen to twenty-five years, as in Holland and Algeria. In Germany their life is estimated at between thirty and forty years, although on the Elberfeld division of the Prussian state railways it is not considered that they will last more than fifteen years, or the same time as the best oak ties. A life of fifty years is sometimes estimated, and it is possible that ties of good design and material and under favorable conditions may come up to this estimate. The steel ties now being tried on the New York Central Railway are estimated to have such a life. The life of rails, however, is said to be less when laid on metal ties than on wooden ties, owing to more rapid wear. Mr. Couard, of the Paris, Lyons and Mediterranean Railway, France, has compiled statistics showing this result, and similar results, but to a less extent, have been noted on the Northern Railway of Austria. The quality and character of the material of the rails, however, is a point of very great importance in consideration of this question.

The question of metal track was among the subjects considered at the International Railway Congress, in 1885 and 1887. The conclusions of the congress held at Brussels, Belgium, in 1885, were as follows:

(A) The congress is of opinion that tracks on metal cross-ties, considered from a technical point of view, can compare favorably with tracks on wooden ties, both for lines with heavy traffic and for lines with light traffic. The congress is also of opinion that the tracks on metal ties can also compare favorably with those on wooden ties from a financial point of view; but it is well in each particular case to make a comparison between the two types of tracks, taking into account the cost of materials, the cost of labor for maintenance, and the probable durability of the materials; the result of the comparison will show which type of track should be adopted.

(B) The congress is of opinion: (1) That for main lines with continuous and heavy traffic, and for strategic lines, it will be well to adopt a stronger tie than that for secondary lines, or lines with lighter traffic, at least for such of the latter tracks as are not likely to become main lines within a short time. For lines which are only secondary provisionally, the resistance of the track may be diminished until the line becomes a main line, by increasing to a certain extent the spacing of the ties. (2) That for secondary or light lines, it is well to employ ties lighter and less expensive than those adopted for main lines, lines with heavy traffic, or strategic lines.

(C) As to the most favorable form and dimensions to be adopted for a metal cross tie, the congress is of opinion that the results of experience, so far, are not sufficiently conclusive to allow of the recommendation of one type to the exclusion of others.

The opinions of the congress held at Milan, Italy, in 1887, were as follows:

(A) The opinion expressed by the congress of 1885, as to the relative merits of metal and wooden ties from a technical point of view, is not weakened by the experience of the last two years; and the use of metal ties is increasing.

(B) As to the relative cost of the two systems, taking into account the net cost and the durability, the result is a question of the type of tie, and depends entirely upon local circumstances and the state of the metal market.

(C) As to the maintenance expenses, for lining and surfacing, the question does not appear to be sufficiently demonstrated for lines with heavy traffic and fast trains. For lines with moderate traffic and slow trains the opinion of the majority is that the metal ties present advantages, especially after sufficient time has elapsed for the earthwork and road-bed to have settled to a good bearing and for the fastenings to have become well consolidated.

(D) For ties of the Vautherin or inverted trough type, it appears well to state that the use of a homogeneous metal is desirable.

The congress held at Paris, France, in 1889, arrived at the following conclusions:

While metal ties present many favorable and advantageous points, the experience with them has not been sufficient to justify any final decision in their favor against wooden ties. Recommendations were made that each management should select two trial sections, 1,640 to 3,280 feet in length, and lay one with metal ties and the other with wooden ties; both sections to have as nearly as possible the same conditions of grade, alignment, road-bed, ballast, and traffic. The trials should last long enough to enable definite conclusions to be arrived at. The special points to be considered and reported upon would be as follows: First cost; cost of maintenance; cost of renewals; approximate life of ties; effect on the rails; best types or forms of ties; general cost, taking renewals into account.

Mr. Bricka, chief engineer of the French state railways, estimated that at the end of 1884 there were 12,400 miles of metal track throughout the world, of which 6,200 miles were in Europe. The tables which I have compiled for this report show a total of 24,800 miles of metal track.

While the general adoption of any one form of tie can not be predicted with any certainty, yet the combination of heavy steel flange rails and steel cross-ties may be considered as the standard type of track of the future for main lines at least. At a meeting of the Cleveland Institution of Engineers (England), in June, 1889, Mr. Jeremiah

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NOTE.—In a paper on "The Improvement of Railway Track," presented at a meeting of the American Society of Railway Superintendents in April, 1889, I called attention to the importance of the metal track question, and also suggested that the committee on roadway should consider, among other matters, the question of the advantages of steel ties for main lines with heavy traffic and for prairie lines, with the desirability of making any recommendations on this point as also on the question of metal tie plates on wooden ties. I have also discussed this question in a paper on "The Improvement of Railway and Street Railway Track," read at the annual convention of the American Society of Civil Engineers at Seabright, N. J., in June, 1889.

Head, M. Inst. C. E., the eminent engineer, prophesied that the standard track of the future would consist of 100-pound rails, laid on steel cross-ties.

Apart from its use for ordinary railway purposes, however, metal track is very extensively used for military railways; for light railways for general purposes, such as feeders to main lines, etc.; for street railways; for portable railways on plantations, etc.; and for contractors' temporary lines. Metal ties are also used in mines and collieries.

TYPES OF TRACK.—In considering the results obtained by past experience with metal track, the various forms already tried may be divided into three classes, as follows:

1. Cross-ties.
2. Longitudinals.
3. Bowls or plates, arranged in pairs and connected by tie-rods transverse to the track.

(1) *Cross-ties.*—This is by far the most extensively used of any of these types, and it has been more rapidly and more widely introduced and extended than either of the others. From this and from the results attending the trials under varying conditions, it may be considered that this is the most advantageous type, and will be the standard type for metal track. In saying this, it must be clearly understood that it is the *type* only which is referred to, as there are innumerable forms and patterns of cross-ties, with which various results have been obtained, as will be seen from this report. Track of this type has been tried in many countries and has proved satisfactory under conditions of the most widely varying character, from European railways with good road-beds and heavy rails, carrying heavy traffic, to prairie and hill country lines. It is especially significant that it has given excellent results and has been widely introduced under conditions of track, traffic, etc., which are practically similar to the conditions which would obtain in service in this country. This type of track has been so widely used that the various forms of ties can not well be summarized here, but some notes are given further on, and full particulars are given in the descriptions of the experiments made on different railways, as shown in Part I.

(2) *Longitudinals.*—This type of track is only used to a limited extent, and, as shown by special reports and other information, their use is not increasing. The construction of the track is more difficult and requires more labor than that with cross-ties. Maintenance, renewals, and repairs are less easily managed, and greater care must be paid to the ballasting and drainage. On the other hand, it has the advantage of giving the rails a continuous support, and, consequently, with a well-packed road-bed, would make a very smooth-riding track, but probably at a higher cost than an equally good track of another type. The construction of the road-bed and arrangement of the ballast involves con-

siderable care and cost, as, owing to the difficulty of drainage, special means have to be taken, by the use of courses of large rough stone or drain-pipes, to carry water away quickly. Longitudinals have been adopted for the city railway of Berlin, Germany, having been proved the best for reducing the noise of passing trains on this viaduct line connecting main lines of railway. It was originally thought that longitudinals would make a better and cheaper track, avoid shocks at the rail-joints, and, by their long bearing in the ballast, require less work of maintenance. Also, that lighter rails could be used with the continuous bearing. It is, however, difficult to maintain the ballast so as to keep a continuous and even bearing inside the longitudinal. The economy in material by the use of longitudinals is reduced or negatived by the necessity of using transverse connections of ties or tie-rods to hold the track together and maintain the gauge. This system is awkward on curves, and renewals are difficult. Each piece must be bent hot at the works, or have the holes for the rail fastenings made to fit a certain radius of curve. In a report on a derailment accident, in May, 1889, on the East Somerset Division of the Great Western Railway (England), the track of which was laid with bridge rails on longitudinal timbers connected by transoms, Colonel Rich, the government inspector, stated that it is difficult to know if longitudinals are thoroughly packed until the trackmen watch an engine passing over the places which have been under repair, as the stiffness of the rail and longitudinal keeps the latter level when it may not be properly packed with ballast underneath.

(3) *Bowls and plates* have been extensively used and have given good results, but only under certain conditions. They have been used in India, South America, South Africa, and Egypt. The bowls were originally designed for sand ballast, which answered very well; in India trouble was experienced from the sand flying up through the tamping holes and causing injury to the running gear and journals of the rolling stock, but a few inches of broken stone or brick reduced this trouble. With broken-stone ballast, however, this track did not answer well. In the Argentine Republic, where the surface soil or black loam is the only material available for ballast, the bowls have been used with great success; but even there steel cross-ties are now being introduced. The objections to the bowls in India led to the designing of a form of plates (Denham-Olpherts system) with which good results have been obtained. It is not likely that this type of track will be adopted to any extent. The type, however, is said to be the most economical in material, giving ample bearing to each rail and eliminating unnecessary metal between the rails. This may be correct under certain conditions, as with very light traffic, but under even moderately heavy traffic such track can not be as firm or stable as track in which both rails are securely attached to the same piece of metal. The transverse connection is necessarily imperfect, and does not insure the correct re-

lation of level of the two lines of rails. The track is relatively cheap, easily laid and maintained; the latter are important features in countries where skilled labor is not plentiful. Bowls were first designed by Mr. Greaves, and early experience showed that care was necessary to have the holes and attachments cast accurately as to size and position, and the holes in the tie-bars also accurately placed; carelessness in this respect has caused serious trouble on some roads in India.

MATERIAL.—The question of the material to be used for metal track is one of very great importance. Cross-ties were at first made of wrought iron, but with the introduction of processes for making mild steel at a low cost this material began to be used, and has now practically superseded iron. The engineer of the Great Central Railway of Belgium, however, considers iron preferable. The steel used is made by the Bessemer, Thomas, or Siemens-Martin processes, and must be of a mild grade. This material possesses the qualities of homogeneity, malleability, and ductility. (As several translators have erred on this important point, I may mention here that "flusseisen" is the German technical term for "mild steel.") Mr. Post, of the Netherlands state railways, considers that the metal should be capable of resisting a tensile strain of 25.4 to 28.6 tons per square inch, with a minimum contraction of 30 to 40 per cent. The steel for ties of the Indian State Railway pattern, for India, for the Mexican Railway, and for the Santa Fé and Cordoba Great Southern Railway in the Argentine Republic, is specified to be equal to a tensional strain of between 26 and 31 tons per square inch, with a contraction of 40 per cent. of the tested area at the point of fracture. Mr. F. L. Delano, of the bureau of rail tests, Chicago, Burlington and Quincy Railway, states that he considers that the kind of metal which it would be safe to use depends considerably upon the shape of the tie; whether from its shape it sustains much flexure in use or is pretty stiff and rigid; for the shapes which appear likely to come into general use he thinks that a .25 per cent. carbon Bessemer steel would answer the purpose well, but that for ties which are liable to considerable flexure a milder steel would probably have to be used.

Mr. Bricka, in his report to the minister of public works (France) in 1885, stated that the tendency to fracture, which was for a long time considered as one of the fundamental objections to metal ties, had disappeared since the employment of mild steel; the ties do not break even in cases of derailment. In some such cases the damaged steel ties were straightened out to proper shape and put back in the track where they continued to give good service. As showing the malleability and ductility of the steel, he quotes a clause generally inserted in German specifications for mild steel ties, which explains the facility with which certain forms of ties requiring bending of the metals are made in Germany. Some engineers consider that the operations mentioned do not affect the strength of the tie, but Mr. Bricka thinks it doubtful if the metal does not suffer. The clause referred to is as follows:

> A tie is to be flattened out cold under a steel hammer, and then bent double at the middle, so that the diameter of the circle at the part bent shall not exceed three inches. During the operation the metal must not show any break, crack, or lamination, but must remain intact.

In a note appended to his report and dated October, 1886, Mr. Bricka gives some interesting particulars of tests made on ties manufactured from hard steel, suitable for rails, showing that mild or soft steel is not so necessary as is generally believed. The tests were made at the St. Nazaire Works, with ties of the latest type for the Northeastern Railway of Switzerland, but with the top table .4 inch thick throughout. The drop tests were made with a tie resting on supports 3.508 feet apart, which sustained without breaking or cracking, successive blows of a ram of 660 pounds with heights of drop of 10 inches to 6 feet $6\frac{3}{4}$ inches; the final bends were only 6.08 inches. The pressure tests were as follows:

(1) Tie resting flat on an iron surface, the load applied through the flange of a rail. The tie sustained no sensible permanent deformation up to a load of 33,000 pounds; then the deformation began and continued steadily up to a load of 63,800 pounds; when the load reached 77,000 pounds the tie was flattened, but the metal showed no signs of failure.

(2) The tie rested on supports $19\frac{1}{16}$ inches apart and was loaded at the middle as before, but with the head of the rail; the load was raised to 35,000 pounds without permanent set; then the bending began, and with 44,000 pounds was .20 inch; under a load of 45,100 pounds, deformation began and continued until the tie was flat at the middle, the arrangement of the apparatus not permitting a bend of more than 6 inches. The upper table was then put into shape in a press and the sides bent till the tie assumed somewhat its original shape; the metal showed no cracks or other signs of injury. These tests show that ties of hard steel will support, like those of mild steel, the shocks of engine and car wheels in a derailment without breaking and without being made unfit to be continued in use, except temporarily. Hard steel would have the advantage of increased rigidity and would give, if proper care were taken in piercing the holes for the fastenings, almost a complete guarantee against distortion of the holes by wear.

In regard to the injury to mild steel ties in case of derailment, at least one railway in India has put up an hydraulic press for the purpose of bending to shape any ties that may be bent or distorted by such accidents. A thickness of .52 inch for the top table is considered to be sufficient to withstand the blows of derailed wheels. A cast-steel tie, known as the Sampan tie, has been patented in England. For longitudinals, wrought-iron is used almost exclusively, though perhaps mild steel may be employed to a small extent. Bowls are usually of cast-iron, but pressed steel has been used in India. The plates used in India are of cast-iron. Wrought-iron plates, bent to form practically bowls, have been used in Egypt.. Cast-iron is generally considered unsuitable for such work, but it has been very extensively employed for bowls and plates in India, South America, and elsewhere, with satisfactory results and a low percentage of breakages.

FORM AND DIMENSIONS.—Different methods have been tried for giving the inward inclination of 1 in 17 to 1 in 26 of the rails, in accordance with the very general practice in most countries. Cross-ties were at first bent to a curve, but that resulted in a tendency of the track to rock if the ballast was packed too hard in the middle or not hard enough under the rails; the tie also tended to straighten, which thus widened the gauge. To obviate these objections, the ties were then made with the middle part horizontal and then bent up toward the ends, which bending could easily be done with steel ties: this was a great improvement, but the ties still had a tendency to rock under the trains. The horizontal tie gives the best results in stability of the track, and to allow it to be used, while avoiding the necessity for tie-plates, the Hosch Lichthammer plan was designed in Germany, in which advantage was taken of the malleability of mild steel, and the top table of the tie pressed to the desired inclination at the rail seat. In the Post tie, extra metal at the rail seat gives the inclination and adds to the strength. In the steel ties for the Indian state railways, which are stamped to shape, the top table is bent up at the rail seat in the operation of stamping. Mr. Bricka suggested, in his report, that it would be simpler to modify the shape of the rail-flange to give the rail the desired inclination. This idea has been suggested by other engineers at various times. Ties with the top table horizontal and with tie-plates to give the rail this inclination are used in Holland, Germany, and Austria, but generally add to the complicated character of the track. With longitudinals the inclination is usually given by tie-plates, or by tilting the longitudinal by means of packing pieces or saddles on the cross-tie connections. With bowls the rail seat is cast at the required inclination. In this country, where the rails are laid without such inward inclination, no bending or tie-plates would be required for this purpose.

The cross-section of nearly all the cross-ties employed to any extent is derived from the type invented by the French engineer, Vautherin, the first trials of which were made about twenty-five years ago, on the Paris, Lyons, and Mediterranean Railway (France). This type has a flat-top table, inclined sides flaring outward from the top and with narrow horizontal flanges on the bottom edges; it formed with closed ends an inverted trough filled with ballast. The flat-top table furnished a good seat for a rail flange, tie-plate, or chair, but the lower flanges were objectionable, reducing the stability of the track by preventing the proper settling of the tie in the ballast and not being wide enough to give any bearing in the ballast; this objection was not felt with fine sand ballast. To obviate this difficulty some engineers, including those of the Alsace-Lorraine railway and Wurtemburg state railways, in Germany, modified the original plan by substituting for the flange a rib of triangular section; this did not diminish the moment of inertia of the tie, but it protected the edges from damage by blows when being tamped. Another modification, forming what was known as the Berg-and-Mark type of tie (Prussian state railways), consisted in abandoning the bottom flange or rib, and bending the lower part of each side to a vertical position; this answered very well, the tie bedding itself well in the ballast and having less tendency to shift than if the sides were inclined for their whole depth. This again was modified by inclining the vertical part of the side slightly outward, the change in direction being made by curves instead of angles, and adding a rib to the bottom edges. In the Haarmann system the top table is comparatively narrow and the sides nearly vertical, with wide flanges at the bottom; the edges of these flanges are turned down slightly to retain the ballast. The ends are closed by riveted plates. Mr. Bricka, in his report, stated that the objections were, the difficulty of ballasting the raised part, the chance of breakage, and the less height for equal weight than ties with inclined sides. The Hilf type has a middle flange or rib along the under side of the top table. The Post type has the sides flaring out in two planes, the cross-section being a portion of a polygon. The Indian type is rounded, having a flat top and curved sides at the rail seat, and an arch section at the middle. The ties of these types on different railways vary of course in details of section, thickness, etc. The tie of the Standard Metal Tie Company, New York, and one tried on the Eastern Railway of France, are channels laid in the normal position with the open side upward; the bottom is flat and the sides are vertical in each case. The Bernard, Severac, Lavalette, and some other cross-ties are built up of angles, channels, beams, and plates.

The system of metal longitudinals includes the Macdonnell, in England; the Hartwich, Haarmann, Hilf, and Rhenish, in Germany; and the Hohenegger and Serres-and-Battig in Austria.

In regard to the thickness of the metal, this has been too often reduced so much, in order to reduce weight and cost, that the tie cracks or splits after being in service for a comparatively short time. It has been customary to make the metal of uniform thickness throughout the length of the tie, but Mr. Post's tie (Holland) has been designed to give an economical distribution of metal; the rail seats are of extra thickness to insure ample strength, additional metal is added at the holes for the fastenings, and the middle of the tie is made only thick enough to give the necessary strength and stiffness; these variations of thickness are given during the operation of rolling.

Mr. J. W. Jones, of the Indian state railways, writes as follows in regard to this point:

> Railway engineers would do well by refusing to have anything to do with ties which are only three-eighths inch thick; one-half inch thick give much better results and are cheaper in the end.

A thickness of 0.52-inch is now very generally used in Germany for the middle portion of the top table of the cross-ties. Experience on the Wurtemburg state railways (Germany) is said to have shown that an iron cross-tie with metal one-half inch thick stood an ordinary derailment very well without alteration of the gauge or any serious deformation, while ties in which the thickness of the body had been reduced to eleven-thirty-seconds inch, with strengthening rib, were so badly deformed by the same derailment as to require to be renewed. In his report of 1885, Mr. Bricka (France) stated that the thickness averaged about 0.32 or 0.36 inch, but was as low as 0.24 inch in the parts subjected to the least strain; at the rail seat it was rarely less than 0.32 inch, and was sometimes as much as 0.40 inch. The tendency has been to increase these dimensions, as it has been observed that under the passage of trains there is less vibration and noise with the heavier than with the lighter ties; and this stability, which causes greater economy of maintenance, is attributed largely to the extra thickness of the metal. Special advantages in stability and in maintaining a good bed or ballast under the rail seats are claimed for the Post and other systems in which the tie is made narrow and deep at the middle.

WEIGHT.—This is too frequently sacrificed to mistaken ideas of economy, with expensive results. In the first place, the metal must be thick enough to stand the shocks and vibration to which the ties are subjected in service without cracking. In the second place, the tie must be strong enough as a beam; otherwise it will give way and become distorted under the traffic. In the third place, the tie must have weight enough to hold the track down firmly, making it solid and stable. In several designs of ties the metal is very thin, the metal being strengthened by corrugations. The designers probably lost sight of the third requirement above mentioned or did not understand its significance. It is probable that the corrugations might in themselves be the cause of failure of the tie, cracks starting at the angles of the corrugations, as has been found to be the case in South Australia and elsewhere. The cause of these attempts to reduce weight is the eagerness of inventors to produce a cheap tie which will appeal to the financial side of railway companies. If the reduction in weight is carried too far, and a very little may be too far, the tie will be a dear one, as, even if it does not crack or otherwise fail, it will make a loose track, requiring continual attention and tamping, instead of effecting a reduction in maintenance. This point is briefly discussed in my remarks on Mr. Post's paper on "Steel Ties" (Bulletin No. III, page 35). It may be noted with advantage that in Germany it has been found generally desirable to use ties of greater weight than those first adopted, as the cost of maintenance was thereby reduced. In England too it has been found that a certain weight is necessary in order to give the tie a holding or anchorage in the ballast. This is the general experience elsewhere. These results of experience show that the various attempts made by inventors to reduce the material and weight to a minimum, without considering some imperative conditions, are not steps in the way of improvement, but tend to throw discredit on metal track in general and to render inefficient some forms of ties which might otherwise be of some merit. A very large number of failures of metal ties are due to too light weight.

The engineers of the Bavarian state railways consider that a weight of 139 pounds should be the minimum for ties for lines with ordinary traffic. Mr. Heindl, the inventor of the ties used on the Austrian state railways, considers 175 pounds the minimum under heavy traffic on main lines. In view of experience elsewhere, however, this seems to be too heavy. Both Mr. Post and Mr. Bricka consider that the steel ties of the Post type in use on the Belgian State Railways are too heavy, but I am informed that they were adopted on account of the great weight of some enormous locomotives which haul over these lines the "overland" train between Ostend and Brindisi. In a paper published in the bulletin of the society of civil engineers, France, April, 1885, Mr. Post stated that some engineers sent to England to examine the railways attributed too great an influence to the weight of the track, and arbitrarily condemned metal ties because they calculated that the wooden ties were heavier. But in order to give the correct value of this argument, it is necessary to know the actual weights of ties of different ages, and some lots of oak ties, taken at random from the tracks of the Belgian state railways and the Netherlands state railways, were therefore weighed. The new ties showed a variation of 42 per cent., the heaviest weighing 173.8 pounds and the lightest 99 pounds, or 11 pounds lighter than the 110-pound steel ties which had been in service for some years. Of the old wooden ties at the end of their service there was a variation in weight of 32 per cent., the heaviest weighing 114.4 pounds and the lightest 77 pounds, or 33 pounds less than the steel ties. The weight of the wooden ties diminishes materially with age, by losing the sap, etc., by which the width of the tie and the bearing of the rail are reduced, and the average weight is only 129.8 pounds for new and 99 pounds for old ties. These figures show the weakness of the argument in favor of wooden ties on account of their weight.

Mr. Bricka, in his report of 1885, stated that at first cross-ties had a weight of only about 77 to 88 pounds, owing to a desire for cheapness, but experience showed this to be insufficient. German and Dutch engineers have estimated that the work of maintenance is less with heavy ties than with light ones, and have increased the weight to 99 or 110 pounds. Ties weighing 129.8 pounds have been used on the Würtemberg state railways, 138.6 pounds on the Bavarian state railways, and 132 to 154 pounds on the Austrian state railways. According to the opinion of many engineers, flange rails on 110-pound steel ties make a very satisfactory track; superior to track on wooden ties. The standard weight might be between 110 and 132 pounds, and even the latter figure might be exceeded in exceptional cases of heavy and fast traffic. He comments upon the heavy Heindl ties used on the Austrian state railways, that the noisy, destructive, and unpleasant vibrations are not experienced with ties of sufficient weight. This is an important point, as the absence of such vibration tends to lessen the disturbance of the track and consequently the work of maintenance.

According to an article in the Indian Engineer, of Calcutta, August 1, 1888, ten ties—the usual number for a rail length of 30 feet—weighing 126 pounds each, will cost, at $30 per ton, or $1.68 each, $16.80; while by increasing the weight to 168 pounds per tie the ten ties would cost, at the same rate per ton, $22.50; but if the latter will last thirty years under conditions of traffic which will wear out the former in twenty years, the cost of material for the heavier track for sixty years will be $45 against $50.40 for the lighter track, or a saving of nearly $1,000 per mile, besides the saving in renewals and the advantage of a more stable track by the use of the heavy ties.

Ties open at the top and filled with or buried in the ballast have their weight in the track very largely increased. Of this type are the Severac, Bernard, and "Z" ties in Belgium; the channel tie of the Eastern Railway of France, and the "Standard" tie now being tried in this country.

MANUFACTURE OF CROSS-TIES.—Cross-ties of trough section are either rolled or stamped to shape. The wrought-iron and many of the steel ties are rolled, but large numbers of steel ties are stamped to shape in hydraulic presses from flat or bent plates. The steel ties of the Indian state railways pattern are made of plates rolled to the rounded channel section, which are cut into lengths; each length is then put into one press which shapes the ends, and then into another press which stamps the lugs for rail fastenings. The Phillips steel ties used in Queensland are stamped to shape from flat plates. Of the steel ties now being used in this country the "Hartford" and "International" ties are rolled, while the "Standard" ties are stamped by hydraulic presses.

There should be as little working of the metal as possible, as all such working tends to disturb the molecular construction of the metal and to reduce its strength. Annealing has been tried on the Netherlands state railways with success from a technical point of view, but the operation is generally too expensive.

In designing a tie its manufacture should be taken into account, as all handling and all additional shop-work adds considerably to the cost of its manufacture. Ties in which much riveting is required, as in the Webb tie in England, the Severac and Bernard ties in Belgium, etc., are not likely to come into general use. As has already been stated, the ties of the simplest form have the best chance.

In Germany and Holland, and probably in other countries, the contracts for metal ties contain a "guarantee" clause similar to the European contract system of guaranteeing rails. This clause requires the manufacturer to replace all ties which break or show defects during a certain term of years; generally three or five. This helps to secure better material and more careful manufacture, and any hidden defects which escape notice during inspection will almost certainly show themselves within the guaranty term.

Preservative Treatment.—In some cases the ties are used as they come from the rolls or press; in other cases they are dipped in or painted with tar, oil, or some composition. The object of this treatment is to prevent rust or corrosion. In open line and in ordinary ballast there is not much danger of corrosion, but it is liable to occur in tunnels or damp places, and in slag or cinder ballast; this is due largely to the sulphuric acid and carbonic acid in the ashes, slag, and smoke. In a paper on "Steel Ties," by Mr. Munday, A. M. Inst. C. E., read before the Civil and Mechanical Engineers' Society (London), in January, 1888, it was stated that all ties should, if possible, be dipped while hot in a preservative solution. But as this can not be done with rolled ties without reheating them, the solution should be kept at boiling point by a steam coil. Rapid-drying is an advantage obtained by dipping hot, as wet, dirty freight and the smell of the wet solution are objected to on board ship (for export), while in some cases the dock laborers have refused to handle the slimy metal sent down from the works. Pressed ties can be taken hot from the press to the bath, care being taken not to set fire to the inflammable mixture. If dipped cold it should be done some time before shipping, so that a sufficient quantity for a cargo may be stacked and dried. A solution recommended for ties and rails is as follows: Two gallons of boiled tar, one-half gallon of mineral turps, 1 gallon of vegetable oil. The tar is boiled first, and the other ingredients then well mixed in. The turps constitute the drier, and the larger the proportion of this the quicker the drying is effected; but as it is highly inflammable great care must be taken in dipping hot metal. The composition invented by the late Dr. Angus Smith (England) and well known by his name, is a solution of coal pitch in coal tar naphtha; it may be used as a paint or bath, and the metal should be hot. There is also a composition consisting of pitch and tar with a little tar oil and dry lime; rock asphaltum melted up and mixed with this gives body and sets hard like enamel. A black varnish solution is used for the steel ties of the Indian state railways pattern. The "Hartford" ties, on the New York Central Railway, are treated with Dr. Angus Smith's asphalt composition, applied at a temperature of 300 degrees Fahrenheit.

Fastenings.—In any system of track it is desirable to have as few separate parts, and as few different or special kinds of parts, as possible. An increase in the number not only increases the labor and cost of track-laying and maintenance, but it is the general experience of the perverseness of things that the right pieces are not at hand when wanted. The forgetting or delaying to send a keg of special bolts, clamps, etc., such as are sometimes required at curves or in other places, may seriously interfere with the work. In this respect the steel track of the Indian state railways, and of the local railways of Belgium, presents many advantages; the ties and two steel keys to each tie being all the material required on any part of the line. Where different degrees of adjustment of the gauge are effected by different sizes of clamps, washers, etc., the system is still more troublesome and complicated, but at the same time it must be remembered that with metal ties the fastenings are supposed to require far less attention than those with wooden ties. With a proper fastening there should be no vibration to cause noise, rattling, and wear; and experience has shown that such fastenings can be made. Where double-headed rails are used, they may be carried in special chairs, as on the London and Northwestern Railway (England), and the Western Railway (France,) or in ordinary chairs, as on the Midland Railway (England), the state railways, (France), etc. Little need be said on this point, as the double-headed or bull-headed sections of rails are never likely to be introduced into this country for regular service, and their use in other countries is comparatively limited.

The ordinary flange rails may be secured direct to the ties by different forms of fastenings, as follows:

1. Bolts and clamps.
2. Bolts, rivets, and clamps.
3. Keys.
4. Gibs and cotters.
5. Rivets.

(1) *Bolts and clamps.*—With many systems of metal track the fastenings consist of bolted clamps. The heads of the bolts are usually tee-shaped (⊥), so that they can be inserted from above, through a slot in the top table of the tie. The bolt passes through a loose clamp which holds the flange of the rail, and the nut is screwed down upon the clamp; a washer or nut-lock is usually interposed, but by the use of a grip thread on the bolt the nut-lock may perhaps be dispensed with, except under severe conditions of traffic, making four pieces less to each tie. The bolts are usually seven-eighths inch or 1 inch in diameter, and the nuts should be of ample depth, so as to give a large thread-bearing. Various forms of clamps are used; in some cases the clamp bears on the rail and the top of the tie, leaving the bolt to resist the thrust of the rail; in other cases, as in the Ruppel system, widely used in Germany, a lug on the clamp fits into the bolt hole in the tie, and so relieves the bolt. In the Roth-and-Schuler system, used on the Baden state railways and with the latest form of tie on the Netherlands state railways, a rectangular washer rests on the tie and transmits the thrust of the rail to the bolt, and a clamp holds the rail and keeps the washer in position. The advantage of a bolt fastening is that it gives a firm hold and can be easily slackened or tightened.

(2) *Bolts, rivets, and clamps.*—In some systems of metal track one side of the rail is held by a riveted clamp and the other by a bolted clamp, the latter being generally on the inner side of the track. This plan is in use in Queensland, Australia.

(3) *Keys.*—A fastening which has been found very efficient consists of a taper steel key driven horizontally between the rail flange and a lug on the tie or on a chair carrying the rail. The other side of the flange is held by a lug. The end of the key or wedge is split, so that it can be opened out or expanded by a chisel after it has been driven to a bearing, and so prevented from slacking back. This fastening is used with steel ties in Belgium, India, Africa, and Mexico, and has given excellent results as to security and noiselessness. A similar style of fastening is used with cast-iron bowl ties in South America, an iron, wooden, or coiled steel key being driven between the rail and a lug cast on the bowl; as the lug was liable to be broken, a loose lug of wrought iron or steel is now used, being inserted in a socket in the bowl; a cast-iron key is used and bears against the web and flange of the rail.

(4) *Gibs and cotters.*—Gibs held up to the rail by a vertical cotter driven into a slot in the top of the tie, were among the earliest forms of fastenings used in Germany; they did not then prove satisfactory, as the vibration jarred the parts sufficiently to loosen them, so that there was considerable noise and rattling under passing trains, while the jarring frequently resulted in the cracking of the tie. In India, fastenings of this pattern sometimes rusted together, so that they could not be moved without breaking them off; a fastening with cast-iron gibs was designed there, but never introduced to any extent. In Germany and Switzerland, improved fastenings are now used, with an extra gib to give a good bearing for the back of the cotter, and as the metal of the tie is thickened at the holes for the fastenings, there is no trouble from breakage; these improved gib and cotter fastenings are reported to give satisfaction. With the Denham-Olpherts plate tie, used in India, there is a fixed lug or jaw on one side of the rail and on the other side is a loose jaw which is held in place by a horizontal cotter which secures the tie-bar.

Rivets.—Riveting the rails direct to the ties is only practicable for portable railways, but some systems of metal track have been designed in which riveted clips are used, the rails being sprung into position. A fastening described in "Les Annales des Travaux Publics," Paris, April, 1888, consisted of two rail clamps of eccentric form, riveted to the tie in such a way that they could turn on the rivet. The rail being put in place the clamps are turned round by a special wrench or bar, bringing the projecting part over the rail flange; when in position, a projection on the outer side of the clamp fits into a notch in a horizontal spring on the top of the tie. A somewhat similar plan of loose riveted clips has been designed by Mr. Moore for use with cast-iron ties in India.

TIE RODS.—With bowl or plate ties, transverse tie-rods or tie-bars are required, to hold the parts together and to maintain the gauge. Flat wrought-iron bars are generally used, placed on edge and passing into or through the bowl or plate; they are secured by gibs and cotters or by cotters only. These are used in India, Africa, and South America. In the De Bergue system, used in Spain, (and tried in India) the tie bar is underneath the bowls, being held by lugs and U-bolts. In the plate ties used in India, the bars pass through the upper part of the plate which forms the rail seat, and are secured by a horizontal flat cotter. On the Calcutta Port Railway, India, the tie bars are fastened to the rail flange by bolted clamps, being quite independent of the bowls.

With metal longitudinals, the two lines of longitudinals have to be tied together, and various forms of cross-tie connections have been used in Germany and Austria. In some cases ⊤ or angle-irons are used, while heavy cross-ties of the same section as the longitudinals have been used at the joints of the latter. These heavy connections, however, have been found to make the track too rigid, causing a battering of the rails at the joints and an increased wear of the rolling-stock. Tie rods are also used to maintain the gauge; they are tapped into or passed through the webs of the rails and secured by nuts; in some cases they are of round iron and in other cases flat with round ends.

METAL CONTACT.—A common objection is that metal track will be noisy and unpleasant to ride over, owing to the metal contact of the rails and ties. Various methods have been tried and suggested to obviate this, but where good fastenings which will keep tight are used, there is not found to be any necessity for such precaution. Mr. George E. Moore, deputy consulting engineer of railways, India, states that wooden packing, asbestos sheets, tarred canvass, etc., have been tried and found of no value. The Great Indian Peninsula Railway, after several years of experiment, has gone back to iron on iron, and finds the results quite satisfactory. It is principally a matter of getting the fastenings tight and keeping them so. Linoleum has been suggested in Belgium. With the steel ties of the London and Northwestern Railway, England, tarred paper, forming a tough leathery material, is used between the riveted plates. Some of the bolt-fastenings used are found to keep sufficiently tight, and with the key fastenings of the Indian State Railway steel ties and the Z-iron ties in Belgium, the fastening is found to be very efficient in this respect. On a section of the Northern Railway, Austria, where one track was laid with wooden ties and the other with metal ties, it is reported that the noise of the passing of trains was no more disagreeable with one system than with the other; showing that with metal ties and fastenings of good shape and proper weight no trouble from noise or vibration need be experienced. In several cases it is specifically reported that there is no trouble from noise or uneasy riding of the cars.

Adjustment of Gauge.—Where metal ties are to be applied to any great length of track it is necessary to provide some means for widening the gauge at curves, etc. With bowls this widening is effected by the use of different sizes of cotters in the ends of the tie bars; this has the objection of increasing the number of separate pieces required, but to obviate this Mr. Schwarz, of the Burrakur Iron Works, India, proposes to use cotters or keys made of different widths in "steps" or "offsets," so that one set of cotters will give the required variation in gauge. With longitudinals the adjustment is effected usually by means of the rail fastenings. With cross-ties, where bolts are used, the adjustment is effected either by eccentric necks on the bolts, as on the Netherlands state railways; by eccentric washers, as on the Baden state railways and Netherlands state railways; or, where the clamps have lugs fitting into holes in the tie, by means of rail clamps with different sized lugs, as on several German railways. With the first plan mentioned two sets of bolts are required, one for tangents and on curves, and the other at the extremities of curves, etc. The bolts are marked on the ends, so that the ordinary and special bolts can be easily distinguished, and in such a manner that the inspector walking along the track can see if the proper bolts are used and are properly placed. With the clamp fastenings on some of the German railways six sizes of clamps are used, and are distinguished by stamped figures: No. 0, on the outside of the rail, has no projection on the lug in the bolt-hole; No. 1, has a projection of one-twelfth inch; No. 2, one sixth inch; No. 3, one-fourth inch; No. 4, five-sixteenths inch; No. 5, five-twelfths inch. This makes a very complicated arrangement, and can only be successfully carried out where the trackmen and section bosses are carefully instructed and trained. In this country, with the class of labor frequently employed, it would almost certainly be a failure. Even with skilled labor such a system is not to be recommended, as under any circumstances the simplest arrangement possible, with due regard to efficiency, is the most desirable. With gib and cotter fastenings the adjustment is effected by using gibs of different widths. It is usually the outer gib and the small gib at the back of the cotter which are made in diffierent sizes. On the Elberfeld division of the Prussian state railways the outer gib is either $\frac{15}{16}$, $1\frac{1}{16}$, or $1\frac{1}{4}$ inches wide, and the small gib either $\frac{7}{8}$, $\frac{3}{4}$, or $\frac{5}{8}$ inch wide. The above remarks as to complication apply almost equally to this plan. With key fastenings the adjustment is effected by putting one or both of the keys on the outer side of the rail.

Closed and Open Ends.—In regard to the question of open or closed ends for cross-ties, the general and most approved practice is to close them. The reasons for this are apparent; a wooden tie when buried in the ballast presents an end area of about 5 by 8 inches or 6 by 10 inches, equal to 40 or 60 square inches, to resist the lateral motion induced by the passing of trains, especially on curves. Metal ties with closed ends offer a similar resistance, but an open-ended tie presents only its thin cross-section, say one-half inch by 14 inches, or 7 square inches, to resist this movement. Trough ties with closed ends offer in fact a much greater resistance to lateral motion, as not only has the outer end to push against the thickness of ballast beyond it, but the other end has to pull against the ballast within the tie and drag the entire core of ballast inside the tie over the ballast below it, which would require very considerable force, especially with broken stone. The ends of metal ties frequently project below the bottom of the body of the tie. Well packed and tamped ties of this kind will keep the track in good line. The open-end ties of the London and Northwestern Railway, England, are said to give no trouble in this respect; these ties are dipped in tar and then in sand, to give them a rough surface to increase the friction in the ballast, but it does not seem as though such a method would be very effectual. It seems only reasonable, however, that closed ends should give the best results. They may make tamping more difficult at first, but when once thoroughly tamped the track is very substantial. With some of the "International" ties used in this country, only half the end was closed, in order to facilitate tamping. The "Hartford" tie, on the New York Central Railway, has its ends bent below the bottom of the tie. The channel tie used on the Eastern Railway, France, has the bottom bent down, the channel itself being open at the ends. The "Standard" tie, on the Chicago and Western Indiana Railway, has the bottom cut loose from the sides at the middle and bent up inside the tie, which is filled with ballast, so that the resistance to lateral motion is at the middle instead of at the ends of the tie, a feature which is claimed to be advantageous on tracks with narrow width of ballast. The ends may be closed by a riveted plate, by stamping to shape while hot, or by cutting the top corners and bending the top table and sides cold.

Mr. Post, in his paper in the Bulletin of the Society of Civil Engineers, France, April, 1885, gives the following account of trials made to determine the efficiency of closed ends: A certain number of ties with closed ends were divided into three compartments, by riveting two plates on the inside of the trough; the two outer compartments were well ballasted, while the middle one was simply filled. An equal number of ties with closed ends were put in service at the same time. It was soon ascertained that the intermediate plates were superfluous, the ends affording all necessary resistance.

Cost.—As to the cost of ties, while prices are given in several cases in this report, yet the prices of foreign ties are not of much practical value in considering the use of such ties in this country, as the conditions of the various foreign metal markets may differ so much from one another and from the conditions prevailing in this country. Mr. Post stated in 1885 that the cost of a good steel tie should not be more than 125 or 150 per cent. of that of a wooden tie. According to Mr. Meyer, of the Prussian state railways, iron ties weighing 110 pounds and costing $1.73 each, must last twenty-five years, in order not to involve an annual charge of more than 9.8 cents,* which is the average annual charge for wooden ties on German railways.

Economy.—The economy effected by the use of metal ties lies in the great life of the ties, the reduction in maintenance expenses, and the higher value of worn-out metal ties over wooden ties. The economy of the metal longitudinals may be doubted, on account of the extensive preparation of the road-bed to secure proper drainage, and of the work of maintenance required to maintain free drainage. The Mexican railway "will feel the good results of its track with steel ties when the competition with the Interoceanic Railway begins, as the track will be kept in first-class condition at comparatively small cost, enabling the road to sustain a close competition." Mr. Katté, chief engineer of the New York Central Railway, estimates that the use of the steel ties now being tried on that line will effect an economy of 8 to 12 per cent. in renewals, repairs, and maintenance. (See also "Maintenance" and "Conclusion."

Efficiency.—That metal ties act efficiently in making a good track has been conclusively and satisfactorily proved, while by the firm seat and secure fastenings the danger of accident from spreading of the track or overturning of the rails is very considerably reduced. The gauge is also maintained more accurately and the track is kept in better line and surface than track on wooden ties.

Spacing of Ties.—The question of the spacing of the ties is one which should be given careful consideration, and the distance will depend to a considerable extent upon the character of the traffic. On a busy main line with fast and heavy traffic, the ties should be spaced closer than on a line with lighter traffic. The average is about 30 to 36 inches. To secure the best results and the most easy riding track, the ties should be spaced farthest apart at the mid-length of the rail and closest together at the rail-joints. Different arrangements of spacing of steel ties are being tested on the New York Central Railway.

Track-Laying.—This work is generally very simple, except in the case of systems with complicated fastenings. The ties are sent out on the cars, with the fastenings in kegs, or in some cases where bolts are used, the bolts are put into the holes and the nuts screwed on, so that when the tie is put in the track the fastenings are all ready to be adjusted to the rail. With many forms of track the work can be efficiently done by unskilled labor, but it is of course always better to have experienced trackmen, or at least an experienced foreman to see that the work is done carefully and correctly. Careless or inaccurate work will cause subsequent trouble, which will tend to create a prejudice against the track. Poor work will reduce the good results which would otherwise be obtained. A point to be considered is the grade of track labor available. In Europe the grade is, on an average, pretty high. An engineer who has made an inspection of the Panama Railway stated that if wooden ties had not been available and metal ties had been used, there would have been trouble with the fastenings and attachments, owing to the indolent and careless nature of the negro trackmen.

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* This charge is figured even too low. See table for computing annual charges on p. 39 of this report. The metal tie, to be within an annual charge of 9.8 cents on first cost alone, must not cost more than $1.40.—B. E. F.

It is well to issue to the section men printed instructions as to tracklaying and maintenance, illustrated, if necessary, by diagrams prepared with the special aim to make them clear and readily understood. The instructions should be clear, concise, and to the point.

BALLASTING.—Various materials for ballast are used for metal track on different roads. In Queensland, the Phillips tie is intended to be used without ballast, being packed with the surface soil of the country, and in South America the road-bed is carefully built up with the surface soil or black loam as ballast. For ordinary circumstances, such as would obtain in this country, gravel, slag, or broken stone may be used, but care must be taken to consider whether the material, especially slag, is likely to cause corrosion. (See page 26.) The ballast must be clean and free from clay, allowing free drainage. It is essential that the ballast should be thoroughly packed into the tie, and a little work with the tamping bar in the first place will save a good deal of subsequent work in maintenance. The material should only be packed hard at the ends and extending some inches in beyond the rail-seats, leaving the middle of the tie only loosely filled; if the middle is packed hard and the ends not carefully attended to, the tie will have a tendency to bend or "hog," and cause an unstable track. In some cases the ballast is laid in two rows of heaps; one tie is put across each pair of heaps and an engine run over the track forcing them down into the ballast, which is then packed and tamped and loose ballast filled in between the rails. The ballast should generally be flush with the top of the tie; in some cases it is filled in over the tops of the ties, and this practice is carried out with the London and Northwestern steel ties on the Pennsylvania Railway, which are covered with fine broken stone. Particular attention should be given to keeping up the road-bed for the first few months, until the ballast under the ties becomes well consolidated; this work should be charged to construction rather than maintenance. The objection has been made that it is difficult to tamp and pack the hollow ties generally used; experience has shown, however, that while it presents some difficulty at first, yet the ballast, being confined within the tie, is soon compacted by the passage of trains, and requires little subsequent attention. The saving in the quantity of ballast required is shown by the official figures given for the Western and Simplon Railway, Switzerland.

RENEWALS.—With cross-ties, bowls, or plates, renewals are as a rule easily effected, but with longitudinals the work is more difficult. In most cases the fastenings of any one tie can be removed, the ballast dug away, the tie dropped from the rail and removed, and a new tie put in place. Where, however, as on some railways in India, the rails have to be tilted to get the flanges under the lugs when being laid, all the fastenings and both joints of one rail must be removed and the rail tilted and taken out; the free end of the tie can then be raised until the opposite end can be slipped off the rail. In some cases the lugs can be pried back to free the rail flange, and in other cases both rails may be required to be taken out. Renewals of mild steel ties are expected to be very few; the material does not rust to any extent, does not wear under the rail, and is not liable to crack at the holes. Of ties laid on the Netherlands State Railways in 1865, the renewals up to 1887 were only 5 per cent. One of the great advantages of a metal track is that it is not disturbed frequently by renewals, and is thus left in good condition for running.

MAINTENANCE.—It is generally found that the work of maintenance for metal track, during the first two to four years, is as much as, if not more than, that for track in wooden ties; after that period, however, the work becomes less and less, as the track gets well settled together, the fastenings firm, and the ballast consolidated, while with wooden ties the work increases year by year until renewals are necessary. The fastenings being secure, do not require constant watching and frequent attention as with spikes in wooden ties; and an occasional surfacing of the ballast and inspection of the ties and fastenings is all that will be required; nor will, as stated, the frequent disturbance of track for renewals be occasioned, as is the case with wooden ties. It is estimated that on the Algerian lines of the Paris, Lyons, and Mediterranean Railway, the adoption of metal ties has effected a saving of one-fourth of the maintenance work, or $62 per mile per annum. According to Mr. Post, the cost per mile allowed on some of the German secondary railways in 1885, for the renewal of steel ties, was only about one-sixth of the sum for replacing old wooden ties per mile per annum. The amounts were deduced from the statistics of the Rhenish Division of the Prussian State Railways, which has been using metal ties since 1868.

One of the division engineers of the Netherlands state railways, in his annual report for 1884, stated that in order to make a test of the metal track (Post ties), he left one of the trial sections, having a grade of 1 in 83 and a curve of 2,460 feet radius, near Glons, Belgium, for twenty-two months (February, 1883, to December, 1884) without lining or surfacing, only employing one man for thirty-four days' work to inspect and tighten the nuts; the traffic over the line was very heavy, but the track was in good condition at the end of the test. On this division the cost of maintenance per mile of track on steel ties, after three and one-half years' service, was the same as of track on oak ties, but at that time the maintenance expenses of the former commenced to decrease, the track being by that time firmly settled, while it would begin to increase with the oak ties. In Germany the cost of maintenance has been found to vary from $38 to $360 per mile with longitudinals, and from $47 to $107 per mile with cross-ties; the road-bed, ballast, and class of track cause these great differences. On the Rhenish division of the Prussian state railways, the work of maintenance per 100 miles in 1879, was two hundred and seventy-one days' work for track on wooden ties, two hundred and nine days' work with metal longitudinals (23 per cent. less), and 164.5 days' work with metal cross-ties (35 per cent. less).

For the calculation of the annual cost for maintenance and renewals, the following points must be considered:

(1) Annual interest on first cost.
(2) Annual sum laid aside for depreciation.
(3) Value of old material, lessening the depreciation.
(4) Cost of labor in renewals.
(5) Cost of rail fastenings.
(6) Cost of maintenance of the road-bed.
(7) Influence of the track upon the life and repairs of rolling stock.

FROGS AND SWITCHES.—With metal track, wooden ties are very generally used at frogs and switches, but metal ties can as well be used and will give a safer track. These metal ties will cost rather more than the ordinary metal ties, on account of their greater length and weight, and the extra number of holes required. The work of track laying will also be more expensive than the mere spiking of rails, guard-rails, and frogs to wooden ties. But when once well laid and tamped, the track put in good line and surface, and the fastenings tightened up a few times until they take a good bearing, the maintenance of such parts of the track will be light, while the safety will be very considerably increased. Metal ties are in use at frogs and switches in Germany and Switzerland, and their use is to be specially recommended, as at these points the track requires to be kept in excellent condition.

RECORDS.—It is very desirable, wherever metal ties are placed, either for a small experiment or with a view to general adoption of the system, that careful records should be kept of the date of laying, construction of the track, amount of traffic, amount of work done and money spent, notes of inspection, results observed, etc., so that it may be seen if the track is satisfactory and economical. In this way an intelligent idea may be obtained as to the general results of the experiments, from a financial and technical point of view. For convenience in keeping notes, some plan of numbering the ties might be adopted, reckoning between mile-posts, by which individual ties could be located and identified in case of breakage, renewals, tests of different fastenings, etc.

TIES MADE FROM OLD RAILS.—Several devices have been patented for the utilization of old rails for ties, but it does not seem probable that they will be used to any extent. In the first place, it is doubtful that the supply of old rails would be at all adequate to the demand, as rails rejected from main tracks may be safely used for side tracks, and are often so used until very badly worn. The uneven wear of the rails would be an objection in some of these devices, and in others the amount of shop work is quite considerable, entailing an expense which is perhaps overlooked when economy is claimed. Cross-ties of this class have been tried in France and Germany, and longitudinals rolled from old rails have been tried on the Northwestern Railway of Austria. Old rails are proposed for the manufacture of the Durand tie in this country. Where the rails are to be worked and submitted to such treatment as rolling into plates and stamping into shape, it may be doubted if the metal would stand this working successfully, or make a safe and durable tie. It would be especially likely to crack at any corrugations, corners, etc., and at any welded parts; this has been the experience in Austria. There might be a limited field for the use of such ties on lines with light traffic, but it is not probable that they would prove efficient, safe, or economical on main lines and under heavy traffic. Any apparent cheapness in first cost would probably be entirely covered by additional work upon the track.

COMBINATIONS OF WOOD AND METAL.—A very large number of ties have been invented in which blocks of wood are placed under the rail as bearing-blocks, and many inventions of this kind will be found in the list of United States patents accompanying this report. The object is, of course, to combine the elasticity of the wood with the strength and durability of the metal; but the weight of experience seems to show that the combination, or the method of obtaining it, is unnecessary or undesirable. Metal ties can be made which will be in themselves sufficiently elastic, and fastenings can be made which will hold the metal surfaces of rail and tie rigidly together. The use of wooden bearing-blocks has been found unsatisfactory in France, Holland, and India. In regard to the metal ties with wooden bearing-blocks tried on the Eastern Railway, France, Mr. Bricka stated in his report, in 1885, that results obtained with ordinary fastenings did not justify the interposition of a block of wood between the rail and the tie, and that it was probable that there would be a play of the pieces after a time. The "standard" steel tie, in this country, in experimental service on the Chicago and Western Indiana Railway, is of this class; but it differs from the ordinary plan in using blocks of preserved wood, which are compressed before being used, and are placed with the rails resting on the end grain. The claims made are that the preservative process will prevent rotting of the wood, while the compressing and manner of placing will prevent flange cutting. By this compression, the block of wood would be practically as rigid as the metal, but it is of course less vibratory.

TIE PLATES.—A method extensively employed in Europe, and recently in this country, to increase the durability of wooden ties, is to use metal plates between the rail and the tie. This method is extensively adopted in Germany.

The use of metal tie-plates with metal ties adds considerably to the cost, and while they may be of some benefit for ties of light section, yet as a general thing, with ordinarily heavy ties, it is found better to place the rail directly upon the tie, as this plan with good fastenings is less liable to cause noise and rattling. Tie-plates on metal ties are used in Germany and Austria.

GLASS TIES.—Glass ties were made by Dr. Siemens in Germany some years ago, and were reported to have given excellent results as to strength. At a meeting of the Cleveland Institution of Engineers, England, in June, 1889, during a discussion on rails and railways, the president stated that some years previous a number of glass ties had been put down, and the inventor had recently informed him that they were still in service. The reason why they do not generally find favor, he stated, is not that they fracture, but because they were very expensive and there was a difficulty in attaching the rails to the ties.

RACK RAILWAYS.

For rack railways which are to carry ordinary traffic, and which form part of through lines of railway and are not merely lines for excursion travel, steel ties are generally used, as they give a more secure and stable track. Mr. Rinecker, M. Am. Soc. C. E., of Germany, who contracts for the construction of rack railways on the Abt system, stated as follows in a letter acknowledging the receipt of Bulletin III, with my preliminary report:

> I fully concur with the views expressed by Mr. Tratman. Being engaged in the construction of rack railways, I am using only steel ties, on account of their reliability in keeping gauge and of their better hold in the ballast against sliding down grade. Where steel ties fail it is on account of errors in shape or size.

MILITARY RAILWAYS.

Light railways for the conveyance of supplies, etc., are much used in Europe at arsenals, fortifications, etc. The majority of these lines are of the portable type, made in sections, so as to be readily and rapidly laid, removed, and relaid. In France very heavy cannon are transported over such tracks; special cars being used to distribute the weight over a number of wheels. In Germany tracks of this kind are used in field-work and manœuvring. The English army in the Soudan campaign had a light railway at Suakin, and the Italians have also a line, but of a more permanent type, in Africa. In the Turkestan war of 1883 the French army had 66 miles of portable railway, 20 inches gauge, with steel rails, weighing 14 pounds per yard; the track was of the Decauville type. In the Tunis war of 1883 the French army had 43 miles of similar track, but with 24 inches gauge and with rails weighing 19 pounds per yard; this was found to be the more suitable and efficient track for the purpose.

LIGHT AND PORTABLE RAILWAYS.

A class of railway with metal ties which is much used in Europe and in countries where work is carried on by European engineers, is that of light and portable railways. They are of various classes, from the permanent line of 42 inches gauge, operated by locomotives and adapted for country railways, feeders to main lines, etc., down to the really portable lines of 12 inches gauge, operated by horse, mule, or bullock power, and adapted for plantation and contractors' work, etc. Railways of this kind would not only be beneficial by means of the advantages possessed, but would also effect an appreciable saving in wooden ties of the small and cheap kind. The track is made in sections of convenient length, built up at the manufactory, which have merely to be carried by one or two men to the required site, laid end to end, and connected, to form a track capable of carrying considerable traffic. One man can carry a section of the lighter portable class. For the more permanent lines some amount of grading and ballasting is desirable. Curves, switches, etc., are all made in sections, as well as the straight track, and the lines can be laid by unskilled labor. Several firms in Europe have extensive works engaged in the manufacture of track, appurtenances, and equipment for this class of line. English prices a few years ago varied from $1,450 to $1,550 per mile of single track, straight line, of 16 and 24 inches gauge, suitable for animal traction; and from $2,500 to $2,700 per mile for lines of 18 and 30 inches gauge, suitable for locomotive traction. In the well-known system of the Decauville Works, France, light steel flange rails were riveted to steel ties of channel section. (See France.) In England various forms and modifications of this class of track are manufactured by the following firms: Dick, Kerr & Co., Kerr, Stuart & Co., Bolling & Lowe, J. Fowler & Co., W. G. Bagnall, J. & T. Howard, the Darlington Steel and Iron Company, and others. (See England and France.) A form of the Post steel cross-tie is manufactured by the Hoerde Works, Germany, for light railways of 24 inches gauge. The ties are of the usual form, except that the lower part is horizontal and the increased depth at the middle is obtained by bending up the top table. They are 33 inches long, 4 inches wide, and 1 inch deep at the ends, 2.24 inches wide, and 2.2 inches deep at the middle; the thickness is .16 inch, and .24 inch at the rail seats. Some of the ties are of uniform section throughout. The rails are of flange section 6.56 feet long; they are secured to the ties by hook-bolts, the nut being inside the tie. Projecting splice plates are riveted to one end of each rail. Each section of this track consists of two rails, three ties, and four splice-plates; the weight of the section complete is 88 pounds. For further particulars of these railways, see an article of mine on "Light and Portable Railways," in Engineering News, New York, September 6, 1884.

STREET RAILWAYS.

In European practice the use of wood in street railway, or tramway, tracks has been very generally abandoned, especially in the cities. For city streets, the track usually consists of grooved steel rails resting on cast-iron chairs or steel cross-ties or longitudinals. A concrete foundation is almost invariably used for such streets, and quite frequently for suburban and country roads. This system of construction is also adopted by English engineers in other countries, as at Honolulu, Hong-Kong, and Buenos Ayres. Similar systems are being introduced in this country, but to a comparatively limited extent, the style of track with flat rails spiked to wooden stringers resting on wooden cross-ties being still the ordinary practice. Notes on street railway tracks and descriptions of different American and foreign systems of construction will be found in my paper on "The Improvement of Railway and Street Railway Track," read at the convention of the American Society of Civil Engineers, in June, 1889.

CONCLUSION.

In this report information has been given, as shown by the tabular summary, covering experience on nearly 25,000 miles of metal track on railways in foreign countries, or 13.21 per cent. of the total mileage (187,721 miles) of the world, exclusive of the United States and Canada. This percentage is steadily increasing, as indicated by the reports from several railways, in which it is stated that metal ties are being substituted for wooden ties, either in large sections of track or by replacing wooden ties with metal ties as renewals are required. In the face of such figures, based upon official returns and statements, it can no longer be claimed that the metal track question is still upon an experimental basis. The official returns from some countries—Germany, Switzerland, and India, especially—show that the results of experience extending over several years have led in several cases to the adoption of metal track, and that this is becoming the standard track of railways in those countries.

In regard to the statements which have appeared in print from time to time, to the effect that the use of metal ties in Germany has been unsatisfactory and is being abandoned, I may refer to the official statements in this report from the leading railways in that country. These statements show that the results have been sufficiently satisfactory to lead to the entire adoption of metal ties on some lines and their continued and extended use on other lines. The only instance in which they have been abandoned is on the Altona division of the Prussian state railways, and there, as stated in the official return, the reason has been in the nature of the road-bed, etc., rather than in the ties. The agitation made a few years ago by the iron industries in Germany, asking for the increased use of metal ties, only showed that the Government was not putting in these ties on its lines in sufficient quantity to suit the iron trade people, and not that the use of metal ties was being discontinued.*

The most extensive introduction of metal track has been in Germany, India, and South America. In the first two countries steel cross-ties are practically the generally adopted type, although different forms of this type are in use in Germany. Cast-iron is still extensively used in India. In South America the metal ties used are mainly composed of a pair of cast-iron bowls connected by a tie-bar, but even there steel cross-ties are being introduced. The weight of evidence and the results of experience point towards the steel cross-tie, as making the best track and giving the best results in other ways, for heavy service at least, and therefore are destined to become the standard tie for first class track. As to the weight of these ties, it may be considered that for lines with heavy traffic it should be between 120 and 150 pounds, according to traffic and other conditions.

The following brief synopsis will give a general idea of the widespread use of metal track:

England.—Steel cross-ties are being tried on a practical scale on the London and Northwestern Railway and the Northeastern Railway. Experiments on a small scale have been made on other roads.

France.—Trials with different forms of cross-ties are in progress on the state railways. Five of the principal companies have also made experiments, and some of the trials are still in progress.

Holland.—Extensive trials of iron and steel cross-ties have been made on the Netherlands State Railway. The use of the Post steel tie is being extended. Other roads are also using metal ties.

Belgium.—The State has directed the carrying out of extensive trials of metal ties, and the trials are now in progress. The Northern Railway and Great Central Railway are also using metal ties. They are being adopted on some of the local and narrow-gauge lines.

Germany.—On the several state railways extensive trials with metal ties and longitudinals have been in progress for several years, and several hundred miles of metal track are now in service. The use of longitudinals is being abandoned, but the use of cross-ties is rapidly extending, and on some lines they have been entirely adopted. On the whole the results have been very satisfactory.

Austria and Hungary.—Two principal systems of metal track are in service. The Heindl system of cross-ties and the Hohenegger system of longitudinals.

Switzerland.—Metal ties are in service to a considerable extent. The results have been satisfactory and the use of these ties is being extended.

Spain.—Steel cross-ties are in service on a narrow-guage railway, and cast-iron bowls on a broad-gauge railway.

Portugal.—An experiment on a small scale has been made on the state railways.

Italy.—No metal ties are in regular service, but a few have been imported for experiment.

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*Objections to the use of metal ties in Germany come also from the forest administration, for the reason that the market for one of its staple products, beech railroad ties (creosoted), which have been grown in excess, has been limited by the substitution of metal, and hence an unfavorable showing on the balance sheet of many forest districts. Unlike the conditions in our country, in Germany a proper forest policy does not require this substitution —B. E. F.

Sweden.—A few steel ties are in service for experimental purposes on the state railways.

Norway.—No metal track has been tried.

Denmark.—Steel ties are in service on the state railways. The results are fairly satisfactory.

Russia.—Experiments have been made on a small scale, but have apparently been abandoned.

Turkey.—Several miles of track near Constantinople are laid with metal ties.

Africa.—In North Africa cross-ties are in use in Algeria and Egypt, and bowls in Egypt. Bowls and cross-ties are in use in South Africa. Steel cross-ties are reported as to be used on the projected Congo Railway.

Australia.—Steel ties are being used quite extensively in South Australia and Queensland. In the latter colony the track is of a type designed especially for cheap construction of railways in even country.

New Zealand and Tasmania.—No metal track is used.

India.—Metal track is in very extensive use and is being constantly laid. Cast-iron bowls are becoming obsolete, but cast-iron plates (in pairs, connected by tie-bars) are largely used and with satisfactory results. A special form of steel cross-tie is in extensive service on the state railways and other lines, and seems likely to become the standard form of track. It has given very good results.

China.—A few metal ties are to be tried as an experiment.

Japan.—Metal ties were used some years ago, but they have all been taken out.

South America.—In the Argentine Republic cast-iron bowls are very extensively used and with satisfactory results. Steel cross-ties are also beginning to be introduced. Limited trials have been made in Brazil.

Mexico.—Steel ties similar to those now adopted in India for the state railways are in service on the Mexican Railway. The results have been very satisfactory.

The principal point of view from which the metal track question is considered in this country, and the one which was of course specially taken by the Department of Agriculture in calling for the preparation of this report, is that which considers it in relation to forest conservation and the reduction of the consumption of timber. But there are other points of view, from which the subject will be presented in rather different relations. Leaving out of consideration the necessity for reducing the timber consumption, metal track will still present many advantages, which will be especially apparent to railway men. In the first place, it has been proved to be more economical in maintenance than track on wooden ties, and there can be no doubt as to the superiority of a well designed system of metal track in regard to efficiency and safety. A better track may be made, and with such secure fastenings as are in general use, there will be a minimum of danger with a minimum of track work for the running of trains. The overturning or spreading of the rails, which causes so many accidents, can scarcely occur with a well designed system of metal track. There need be little if any extra noise with the passage of trains, and the riding of trains may be as smooth and quiet as on track with wooden ties. In general it may be stated, that steel ties should be adopted as the standard for first-class track on lines with heavy traffic. Steel ties should be introduced as an advancement in railway engineering, and as a step towards practical economy. A good metal track, when once well laid and settled, is in itself a measure of safety and a source of economy in maintenance and operation. This is in relation to the main line, but metal track presents also special advantages for use at stations and yards. A metal track at such places, when once well laid and settled, is practically permanent, and there is a great reduction in disturbance and expense for repairs and in the chances for derailments, which are specially troublesome at terminals, yards, stations, etc. Metal track is also adapted for light and portable railways, street railways, etc.

As regards the relations of first cost and economy, Mr. Walter Katté, chief engineer of the New York Central and Hudson River Railway, has estimated and closely calculated that if the steel ties now being tried on his line last for fifty years, which he estimates as their life, there will be a relative economy of from 8 to 12 per cent. in favor of these ties. The economy is in renewals, repairs, and general maintenance. I have examined Mr. Katté's figures, and have calculated that even if the life be taken as only thirty-three years, there will still be a material saving per mile per annum.

I am particularly pleased to be able to show in this report that this subject is being practically considered and tested in this country, some fairly extensive trials being now in progress. From the results of several years' experience in foreign countries, it can not be doubted that it is entirely practicable to successfully introduce metal track into the United States. American ingenuity and skill will probably produce ties of equal or greater efficiency than those in use in other countries.

This report will show, I think, to railway financiers as well as to practical railway men, the advantages attending the use of metal track. In regard to the desirability of introducing such track, I quote as follows from an interesting letter to me from Mr. C. P. Huntington, of the Southern Pacific Railway Company, in January, 1890:

> I have for several years advocated the use of metal ties along the timberless regions of our lines, and while none of them have as yet been put in use, I think they will be given a trial in the near future. You have no doubt experienced that time and considerable patience is necessary to direct the minds of men into fields of investigation differing from those in which they have been educated, and in the practice of which they have spent a large part of their lives. To this fact I attribute much of the apathy manifested in giving metallic ties a trial; but now, as their merits and those of the various designs in use are being discussed by American writers and engineers, there will be a quickening of opinion about them, which is likely to make them in the next few years a factor of some importance in the discussion of railroad economies.

This report certainly shows the practicability of the matter and its desirability from several points of view. It may fairly be reasoned that what has been successfully accomplished abroad may be accomplished with equal success in this country. I have reported with pleasure that more and more attention is being paid to this matter, and that since the presentation of my preliminary report in February, 1889, really practical trials have been instituted. It is my wish that the present report may prove of some service in keeping alive and increasing the present interest in the matter, and that it may prove instrumental in furthering the practical work in this important direction.

Finally, while I can not predict any general or extended movement in this direction in the near future, I can certainly state that there has been a marked advance within the last year or two, and that this advance appears likely to continue. I think it highly probable that the question of the use of metal ties for railways as a substitute for wooden railways will gradually, steadily, and surely become one of the live problems of railway economics.

PATENTS RELATING TO METAL RAILWAY TRACK.

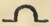
By E. E. Russell Tratman.

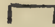
The following list of United States patents relating to metal railway track and other substitutes for wooden ties will be found useful by persons interested in the subject. It could not practically be made anything more than a descriptive index, giving sufficient information to enable any one who wishes to investigate more fully to form some idea of the different types patented, and to find the specifications.

No. 1262; date, July 26, 1839; J. Stimpson.—Transverse frames resting on longitudinal timbers, with inclined braces to hold them in position, and sockets at the top to receive the web of a rail with a very narrow flange.

No. 7799; date, November 26, 1850; H. H. May.—A cast-iron column under each rail; broad circular base; top formed to make a chair for a double-headed rail, and having a projecting arm forming half of a transverse tie-bar.

No 16898; date, March 24, 1857; H. Carpenter.—A short hollow post under each rail, connected by a tie-plate; T-shaped fastening fitting into hollow of post. (See Nos. 35198, 99531.)

No. 18494; date, October 27, 1857; S. A. Beers.—Continuous longitudinal structure, with transverse tie-bars. Saddle-rail of  section.

No. 19704; date, March 23, 1858; S. H. Long.—Cross-ties of channel  section or T section (the latter made of two angle-irons.) Continuous flat plate under ordinary rail.

No. 20620; date, June 22, 1858; W. Bryent.—Combined longitudinal grooved rail and iron pavement.

No. 29693; date, August 21, 1860; Alexander Hay.—A deep support to be driven into the earth under each rail; either flat or twisted into a spiral; flat head, with chair to support rail.

No. 32794; date, July 9, 1861; B. C. Smith.—Wide longitudinal channel sleeper and rail combined, with transverse rods. A raised rib lengthwise of the sleeper forms the rail. (See No. 36579.)

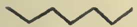
No. 35198; date, May 6, 1862; H. Carpenter.—A cylindrical casting with a wide rectangular base is under each rail; the pairs connected by transverse tie-bars. The flange rails are held in chairs, the bottom of which fits into the cylindrical casting or embraces it like a cap. (See No. 16898.)

No. 35879; date, July 15, 1862; Herman J. Lombaert.—A continuous metal stringer is laid on wooden cross-ties; the flange rails rest on metal tie-plates with one end bent to a hook to hold one side of the flange of the rail. The other side is held by a gib and cotter. Object, to separate the wearing and bearing parts of the rail.

No. 36579; date, September 30, 1862; B. C. Smith.—Longitudinal cast-iron continuous bearing, of channel section, connected by transverse tie-rods. Rail secured to chairs. (See No. 32794.)

No. 38274; date, April 28, 1863; J. Anthony.—Metal chair and tie-plate for flange rails on wooden ties.

No. 53507; date, March 27, 1866; Franz Vester.—Flat cross-tie, with two deep corrugations along its whole length. Ends turned down.

No. 58563; date, October 2, 1866; Swain Winkley.—A corrugated plate of  shape under each rail, connected by a tie-bar.

No. 59112; date, October 23, 1866; Swain Winkley.—A corrugated or buckled iron plate under each rail, connected by a tie-bar; rails held by clamps and keys.

No. 63161; date, March 26, 1867; B. B. Hotchkiss.—A combined track and pavement. Cast-iron frames the width of the track are fitted to receive wooden blocks, to which flat rails are spiked.

No. 66711; date, July 16, 1867; R. M. Holland.—Cross-tie of ⅄ section. Flange cut away for rails. Hinged wedge fastening.

No. 70731; date, November 12, 1867; Henry McCan.—Broad flat transverse base-plates, with longitudinal girders held together by tie-rods. Rails resting on top of girders.

No. 71063; date, November 19, 1867; Leonard Repsher.—Wrought-iron cross-tie, bent up at ends to embrance flange and web of rail, angle-clamp bolted to tie on inside of rail. Bolt through clamp, web of rail, and end of tie.

No. 79016; date, June 16, 1868; William F. Serjeant.—Deep flat tie-bars connect the rails, which rest on, but are not spiked to, wooden ties. At each end of the bars are jaws to hold the base of the rail.

No. 83880; date, November 10, 1868; J. Potter.—Flat transverse base-plate, with two uprights which support continuous stringers, to which flangeless T-rails are bolted,

No. 84023; date, November 10, 1868; A. Van Guysling.—A hollow iron column under each rail; the rail is secured to a chair keyed to the top of the column. The columns are connected by tie-bars at the top; or they may be cast in combination with a hollow transverse base, in one piece.

No. 92874; date, July 20, 1869; W. J. Cockburn Muir (England).—Hollow inverted bowls, connected by transverse tie-bars; the rails are secured by lugs and keys.

No. 94856; date, September 14, 1869; C. G. Wilson.—Two channel irons placed back to back form a continuous stringer, and rest on wooden stringers. The web of a flangeless T-rail rests between the channel irons. The iron stringers are connected by tie-bars.

No. 97020; date, November 16, 1869; A. Van Camp and M. M. Hodgman.—For street railways. A deep rail with flat head and a web corrugated longitudinally is bedded in asphaltic or concrete composition. A groove is made in this composition along the side of the rail.

No. 97224; date, November 23, 1869; John H. Phillips.—Inverted bowls or saucers, having a chair for the rails and being connected by tie-bars.

No. 99531; date, February 8, 1870; H. Carpenter.—A hole is bored at each end of a wooden tie for the stem of a T-shaped metal support; the rail rests on a T-shaped plate, having lugs to hold the flanges of the rail and a stem underneath to fit into the hollow stem of the seat. (See No. 16898.)

No. 101751; date, April 12, 1870; Edward G. Markley.—A cast-iron column, in the form of a truncated cone, is under each rail. On top is a chair for the rail. Tie-bars connect the pairs of columns.

No. 107643; date, September 20, 1870; C. H. White.—Flat transverse bed-plates laid on wooden stringers or cross-ties. The rails are of ∩ or bridge section, and rests on tie-plates having a rib which fits into the rail.

No. 109504; date, November 22, 1870; C. Fisher.—Cross-tie of inverted trough section, with closed ends. Two pockets for wooden bearing blocks. Rail fastened by flat plates resting on tie and rail flange, screwed to the wooden blocks.

No. 112805; date, March 21, 1871; S. M. Guest.—A railway joint chair, combined with an iron cross-tie of T section.

No. 118260; date, August 22, 1871; Elijah Myrick.—A ring-shaped tie-plate, with three studs or pins to be driven into the wooden tie.

No. 121956; date, December 19, 1871; J. Newton.—A rail fastening for iron ties. Flat tie with end turned up, wooden wedge between rail and end of tie, vertical jib and cotter fastening (with serrated cotter) on inside of rail.

No. 123526; date, February 6, 1872; L. E. Towne.—Cylindrical cross-tie with a flat base-plate at each end, secured by a strap passing round the tie.

No. 124521; date, March 12, 1872; R. M. Upjohn.—Longitudinals under each rail, of ⊥ section, with very high vertical web. The rail is of _∩_ section, and rests upon the flanges of channel irons bolted to the vertical web of the longitudinals.

No. 127553; date, June 4, 1872; and No. 130010; date July 30, 1872; John L. Boone.—Ties made of a composition of fiber or other material, saturated with asphaltum and shaped under pressure.

No. 128120; date, June 18, 1872; Joseph H. Connelly.—A longitudinal of concrete is laid under each rail and covered with a continuous iron plate. The rails rest on wooden tie-plates and are supported by chairs.

No. 134418; date, December 31, 1872; James Calkins.—The continuous longitudinals of channel sections have lugs to hold the outer flange of rails; transverse plates project over the inner flange and are bolted to the longitudinals.

No. 135667; date, February 11, 1873; Alexander D. Rock.—Castings of "frying-pan" shape; the rail is secured to a chair on the bowl, and the "handle" forms half of a transverse tie-bar; the ties are connected by diagonal rods.

No. 136067; date, February 18, 1873; J. W. Kern.—A continuous road-bed of Λ section, with the rails laid on the horizontal flanges. Transverse base-plates at intervals. The bed to be of $\frac{1}{4}$-inch boiler iron.

No. 139031; date, May 20, 1873; William H. Sterling.—Ties of a compressed asphaltic or other composition, with wooden plugs embedded in the material to receive the rail spikes.

No. 139518; date, June 3, 1873; W. Peck and H. C. Richman.—Two chairs connected by a horizontal flat tie-plate. Wooden bearing-blocks in the chairs.

No. 140411; date, July 1, 1873; C. W. Gulick.—A flat wrought-iron cross-tie with ribs, to form a channel for the flange of the rail. Fastenings of iron $\frac{4}{10}$ inch diameter under tie, passing up through holes in the same, with ends bent over rail flange. Ties about 5 inches wide and $\frac{1}{2}$ inch thick.

No. 142668; date, September 9, 1873; J. R. Beckett.—Street railways. Transverse rods forming tie-plates for the rails and braces for the wooden stringers.

No. 143407; date, October 7, 1873; P. S. Devlan.—A cross-tie made of two iron plates on edge, fastened together at the middle and widening out to hold a wooden block at each end.

No. 144207; date, November 4, 1873; George Keech.—Longitudinal plates under each rail, with lugs to hold outside of rail flange. Transverse tie-plates project over the inner flange and are secured by horizontal bolts passing through lugs on the base plate.

No. 145250; date December 2, 1873; T. R. Timby.—Bowls of different forms cast on the ends of a deep flat steel or wrought-iron tie-bar. In the end of the bar are holes through which the metal flows and thus secures the casting of the bar. (The method is similar in principle to that of the Chappée tie now being tried on the Western Railway of France.) (See the report.)

No. 145991; date, December 30, 1873; H. L. De Zeng.—Wrought-iron cross-tie of └──┘, U U, or other section. A clip stamped out of the metal holds outer flange of rail; loose clip, secured by vertical key or cotter holds inner flange. (See Nos. 155369; 334696; 380623; 400643.)

No. 146376; date, January 13, 1874; G. H. Blaisdell.—A cast-iron cross-tie of Λ section, with wide flat deep ends, having sockets for wooden blocks. A bolt passes through both blocks and the whole length of the tie.

No. 147563; date, February 17, 1874; P. Kendrick and J. Stokes.—A cross-tie made of two old rails laid parallel, with a wooden block between them at each end, and base-plates if desired.

No. 148242; date, March 3, 1874; George Potts.—Continuous bearing of wood held between two continuous iron stringers of ⊥ section, the top of the web being bent over to hold the rail flange. Bolts pass through the three pieces.

No. 152469; date June 30, 1874; Abram Dehuff.—The rails are spiked at the tops of short wooden piles or stakes, and are connected by iron tie-bars.

No. 155369; date, September 29, 1874; H. L. De Zeng.—A cross-tie of inverted trough section, with open ends, but with projecting wings at ends to prevent lateral displacement. (See No. 145991.)

No. 158437; date, January 5, 1875; S. L. Porter and Duane Peck.—Kite-shaped metal bowls, with the pointed ends between two diagonal tie-bars which form an X. The rails are held by lugs, keys and screws.

No. 161153; date, March 23, 1874; S. L. Porter and Duane Peck.—Modifications of the previous patent, No. 158437.

No. 163187; date, May 11, 1875; S. H. Hamilton.—An iron or steel cross-tie of square hollow section throughout or only at ends. Fixed lugs hold the inner flange of rail, and bolted plates hold the outer flange.

No. 163254; date, May, 1875; H. Reese.—A rolled iron cross-tie of T section; lugs stamped out while hot from the rolls. Bent clip and horizontal wedge fastening for outer flange of rail. (See Nos. 214192; 215675; 272477; also July 13, 1880.)

No. 164793; date, June 22, 1875; Ramon Bañolas.—Cross-ties of I section, carrying longitudinal stringers of ⊥ section, to which flangeless rails of ˥ section are bolted.

No. 166625; date, August 10, 1875; R. E. Nichols.—A continuous hollow bearing, section similar to lower half of letter A; bottom closed; top open with horizontal flanges to carry the rail flange, cross-ties of ⊔ section. Longitudinals and cross-ties filled with broken stone.

No. 171422; date, December 21, 1875; John Quigley.—A cast-iron cross-tie with chair combined, for street-railway track.

No. 172041; date, January 11, 1876; E. E. Lewis.—A cross-tie of + section, with the top vertical flange cut away for the rails, which are secured by wedges. (See Nos. 183, 766; 198, 464.)

No. 176213; date April 18, 1876; George D. Blaisdell.—A cast-iron cross-tie, with wide ends and loose bearing-blocks, all held together by a bolt running through the whole length of the tie.

No. 182984; date, October 3, 1876; Leonora Yates.—Cross-ties of ˥⊔Γ, ‾∨‾, or ‾∪‾ section, the latter being semi-cylindrical, with flanges. The rails are fastened by bolted clamps.

No. 183766; 183767; 183768; date, October 31, 1876; E. E. Lewis.—A cross-tie of + section; rails of different forms. Also a joint tie of ⊥⊥ section. (See 172041.)

No. 185808; date, December 26, 1876; D. S. Whittenhall.—A cross-tie of /\/\/\ section; the rails resting in notches in the top ridges. (See No. 227602.)

No. 186710; date, January 30, 1877; George W. Chandler.—Clay, stone, or concrete ties in two or more pieces; a flat iron strap is laid in a groove along the top and another along the bottom; these plates are bolted together. The rails are held by clamps screwed to the iron plates.

No. 187652; date, February 20, 1877; Walter MacLellan and John P. Smith (Scotland).—Fluted, corrugated, or embossed rectangular bowls, connected by tie-bars; the rails are held by bolted clamps. (These ties are manufactured in Scotland and are in use in India and Australia.) (See the report.)

No. 188087; date, March 6, 1877; H. S. Wilson.—A cross-tie of I section, with fixed and movable rail-clips.

No. 188710; date, March 20, 1877; N. S. White.—A continuous bed-plate under each rail, with cross-ties.

No. 190739; date, May 15, 1877; A. H. Campbell.—A cast-iron cross-tie, with sockets for wooden bearing-blocks.

No. 192842; date, July 10, 1877; A. W. Serres.—A continuous bearing of Y section (in two pieces) under each rail with transverse tie-bars. The web of a flangeless rail lies between the two vertical webs. (This track has been used in Europe; see Engineering News, New York, January 28, 1887, page 73; also Railroad Gazette, New York, August 19, 1887. See report; "Belgium" and "Austria.")

No. 197300; date, November 20, 1877; John Turner.—Street railways. The wooden stringers are connected by tie-rods which have flat plates or washers, held tight against the stringers and rails by nuts. No wooden cross-ties are used.

No. 198060; date, December 11, 1877; John B. Ward.—A longitudinal pipe (for conveying water) under each rail; the bottom of rail curved to fit pipe.

No. 198370; date, December 18, 1877; Josiah Foster.—Hollow box castings, with top and bottom flanges, are bolted to stone blocks; the rails rest on spring plates and are held by hook bolts to the top flanges of the castings.

No. 198464; date, December 25, 1877; E. E. Lewis.—A cross-tie consisting of an old rail with two notches cut to the level of the flange to admit the track rails. Two rails with wooden bearing-blocks used at joints. (See 172041.)

No. 198618; date, December 25, 1877; D. Horrie.—A transverse truss of cast or wrought iron. Horizontal hook bolt fastenings.

No. 200737; date, February 26, 1878; Gustav Lehlbach.—Street railways or ordinary railways. Deep foundation columns under each rail.

No. 201667; date, March 26, 1878; H. A. Haarmann.—Continuous bearing for each rail, with cross-ties. This track has been extensively used in Europe. (See Engineering News, New York, January 29, page 74.) (See No. 219856.) (See Report, "Germany.")

No. 206647; date, July 30, 1878; T. W. Travis.—A hollow cross-tie, with boxes at the ends open on top. The rails are held between two ⊂ clips; the groove holds the flange rail; the upper web lies against the rail web, and the lower web is wedged into the box. See Nos. 214208 and 224808. (Tried on the Philadelphia and Baltimore Central Railway.) (See Report, "United States.")

No. 207242; date, August 20, 1878; J. A. Bonnell.—An inverted trough cross-tie with closed ends and corrugated top. Bolted clips or angle-bar fastenings for rails.

No. 207320; date, August 20, 1878; J. H. Thompson.—A cross-tie made in two pieces, dove-tailed together in the middle. The rails rest on wooden blocks.

No. 210681; date, December 10, 1878; George F. Folsom.—A continuous cast-iron bearing under each rail, connected by iron ties and having sockets for round wooden blocks.

No. 207719; date, September 3, 1878; W. E. Curtiss.—A wrought-iron cross-tie of inverted trough section with flaring sides, having a brace of the same section inside under each rail. The ends are open. Rails secured by bolted clips.

No. 210774; date, December 10, 1878; F. B. Freudenberg.—A wrought-iron cross-tie of somewhat similar section to the preceding one. Hooked clips are riveted on for inside and outside flange on alternate ties, the rails being sprung into place. Long ties for double tracks. Patented in Germany, January 18, 1878.

No. 211697; date, January 28, 1879; Hamilton L. Bucknall (England).—Glass bowls, cross-ties, and stringers.

No. 212127; date, February 11, 1879; James Buckner, jr.—For street railways. Metal saddle plates on the stringers, to carry the rails, and metal tie-bars.

No. 214182; date, April 8, 1879; George P. Osborne.—Safety plates to keep spikes from working loose when driven into sound-deadening material, to be used for elevated railways.

No. 214192; date, April 8, 1879; H. Reese.—A cross-tie of T-section, with the ends of the horizontal table turned down at an angle. Clip and wedge fastening. (See No. (163254.)

No. 214208; date, April 8, 1879; T. W. Travis.—A cast-iron box under each rail, vith broad rectangular base. Tie-bar connections. The rails rest on and are held y vertical wedge clamps. (See No. 206647.)

No. 215675; date, May 20, 1879; H. Reese.—Improvements upon No. 214192.

No. 216846; date, June 24, 1879; L. A. Gouch.—A cross-tie of ─┼─ section, the ongitudinal web being the widest and having its edges turned up or down.

No. 218442; date, August 12, 1879; John Keller.—The wooden ties are spaced far part, and at intermediate points there are bolted to the rail angle-plates with wide laring flanges which project below and beyond the rail-flange, forming a sort of bowl.

No. 218559; date, August 12, 1879; S. Nicholls (of England.)—A continuous broad ed-plate under each rail, for street railways. The rail is formed of two channels, eaving a space between for the wheel-flange ⊐ ⊏.

No. 218603; date, August 12, 1879; A. P. Whiting.—A cross-tie of H section, the op flange cut away for the rails. Bolted clips hold the inner flanges of rails.

No. 218648; date, August 19, 1879; C. F. Wagner (of Austria).—A cross-tie com-osed of two parallel pieces of T-section, fastened together by cross-strips. Bolted lip rail fastenings.

No. 218878; date, August 26, 1879; C. Hanshaw.—A cross-tie made in two pieces engthwise; on one piece are clips for the inner flange of one rail and the outer flange f the other, and on the other piece are clips for the outer and inner flanges, respect-vely. The two pieces are held together by a flat horizontal key driven between ther clips in the middle of the tie.

No. 219856; date, September 23, 1879; H. A. Haarmann of Prussia—(See No. 201667).—A cross-tie of inverted trough section with flaring sides, and a flat or grooved top able. The rail fastenings are ⊏ shaped, with a bolt passing under the rail.

No. 220026; date, September 30, 1879; H. T. Livingston.—A tubular cross-tie of oval section with a flat surface under each rail. Rails fastened by bolts screwed nto the tie. Interior of tie packed hard with straw, grass, etc.

No. 221596; date, November 11, 1879; O. E. Mullarky.—A cross-tie of channel sec-ion ┌─┐ with wooden bearing-blocks wedged inside under the rails. The rails are fastened by bolted clips.

No. 223187; date, December 30, 1879; J. R. Sullivan.—Two separate cast-iron bear-ng pieces connected by a tie-bar. Each rail is secured by a cast-iron wedge.

No. 224808; date, February 24, 1880; T. W. Travis.—A bridge support is placed etween the ties, the top supporting the rail and the ends resting on adjacent ties. The object is to enable ties to be spaced farther apart than usual. See No. (214208).

No. 226308; date, April 6, 1880; A. Greig (patented in England, March 25, 1879).—Flat cross-ties, with one or two grooves along the whole length. A brace or clip is iveted to hold the outside of the rail, and the rail is held against it by a hook-bolt, he body of which lies in the groove and has a nut at the end of the tie. (This sys-em is much used for portable railways manufactured in England.)

No. 227602; date, May 11, 1880; D. S. Whittenhall.—Improvements on No. 185808.

No. 9292 (re-issue); date, July 13, 1880; H. Reese.—(See No. 214192.)

No. 230816; date, August 3, 1880; William Rainbow.—Cast-iron bowls of different orms, of approximately conical shape; they are connected by tie-bars.

No. 230826; date, August 3, 1880; Lewis Scofield.—A cross-tie of ⎍ section. Riveted and bolted clips for rail fastenings. (See Report; "United States.")

No. 231755; date, August 31, 1880; William Brown.—A hollow cross-tie of rectan-ular section, with concave bottom and open ends. A rib at the ends keeps the rail n position, and is fastened down by hooked bolts with nuts inside the tie.

No. 233528; date, October 19, 1880; W. C. Lutz.—A cross-tie of ⊥ section, with the ails secured by flat hooked clips bolted to the side of the vertical web. (See No. 41389.)

No. 235078; date, December 7, 1880; G. H. Gilman.—A cast-iron cross-tie of rect-ngular section, with grooves to reduce the weight. The rails are held by fixed and movable lugs.

No. 235321; date, December 7, 1880; F. A. Williams.—The two broad bearing plates, on which the rails rest, are connected by two transverse tie-plates, placed on edge.

No. 235706; date, December 21, 1880; S. F. Seely.—Metal longitudinals of rectangular form, with flaring sides and ends. Flangeless T-rails are used, with the web bolted against the leg of a T-iron on the longitudinal.

No. 239511; March 29, 1881; Joseph Kindelan.—Rail brace and tie-bar for curves.

No. 240511; April 26, 1881; D. R. V. Goetchius.—A flat tie-bar with wide ends is bolted on to a wooden tie; the ends have lugs for the rail flanges.

No. 240987; date, May 3, 1881; I. W. Fleck.—A cross-tie made of an ordinary rail, head down, with strengthening sections and a broad base-plate bolted to it. It is curved into an arched form, high in the middle, with the ends level for the track rails.

No. 241389; date, May 10, 1881; W. C. Lutz.—A cross-tie of cylindrical form, with flat bearing surfaces for the rails; or with a vertical web on top, with notches for the rails. (See No. 233528.)

No. 241724; date, May 17, 1881; J. C. Rupp.—The tie consists of a block under each rail, with a connecting tie-bar. (See No. 245222.)

No. 242850; date, June 14, 1881; H. Thielsen.—Cross-tie of T-section; in two halves, one under each rail. Bent clips formed out of the metal of the tie. The two pieces keyed together at the middle. (See No. 317244.)

No. 244003; date, July 5, 1881; George W. Vroman.—Each tie is in two pieces, each of which consists of a rectangular plate and half a tie-bar. Lugs are placed diagonally on the plates. The plates are put under the rails, so that the latter will rest between the lugs; the plates are then swung round, bringing the ends of the rods together, and bringing the lugs over the rail flanges. (This is similar to the ties proposed by Mr. Moore in India. (See Report.)

No. 245222; date, August 2, 1881; J. C. Rupp.—The block under each rail is of I-section; and each pair is connected by two tie-rods, forming an X. (See No. 241724.)

No. 245440; date, August 9, 1881; Thomas Breen.—A cast-iron chair or support is placed under each rail, and the pairs are connected by tie-bars. The rails are secured by bolted clamps. (See Nos. 272850 and 294191.)

No. 246888; date, September 13, 1881; G. A. Jones.—A cross-tie of ⊥ section, with the ends formed into a chair. The rail is held in the chair and spiked to a wood block.

No. 247248; date, September 20, 1881; Levi Haas.—A cross-tie made of an old rail with the ends resting on wood blocks; the track rails are secured to the top of the tie. (See 253374, 257572, 282309, 315771, 389464, 391704, 406346, 420299.)

Nos. 249270 and 249271; date, November 8, 1881; E. H. Tobey.—Cross-ties of ⊔ or V section; the rails are held in chairs resting on wooden blocks.

No. 249503; date, November 15, 1881; J. Clark.—A cross-tie of semi-circular section , the bottom fastened to a flat bed-plate the whole length of the tie; the top of the arch cut away for the rail. (See 256199, 259095, 270637, 358144, also August 5, 1884.)

No. 251251; date, December 20, 1881; C. F. Kreuz.—A flat cross-tie with thickened ends to hold the outer flanges of the rails and a flat cross-tie with another flat piece resting on it to hold the inner flanges of the rails. These ties are placed alternately. (See No. 263919.)

No. 251625; date, December 27, 1881; William Morris (England).—Concrete chairs and blocks for railways and street railways.

No. 253374; date, February 7, 1882; Levi Haas.—Iron ties in two pieces, connected by a tie-bar. It is designed to be made of old flange rails. (See No. 247248.)

No. 253381; date, February 7, 1882; Charles F. Herbst.—Cast-iron bolts, rectangular and pyramidical; each pair of bowls is connected by a tie-rod, having a nut on each side of each bowl. The rails are held by wedged and bolted clamps.

No. 254802; date March 14, 1882; J. Conley.—A flat cross-tie in two pieces, with the inner end of each turned up so as to be bolted together. Under the rails the sides are turned down. Clips are stamped out of the metal. (See No. 332384.)

No. 255554; date, March 28, 1882; F. A. Williams.—A cross-tie of shallow inverted trough-section, with broad ends. The rails are held against fixed clips by plates the whole length of the tie, placed on edge, underneath, with a hooked end to hold the rail flange. These plates are secured by a horizontal key in the middle of the tie.

No. 256199; date, April 11, 1882; J. Clark.—Improvements upon No. 249503.

No. 257437; date, May 2, 1882; H. De Zavala.—A cross-tie of ⋀ section, with U-bolts passing under the rail and having nuts screwed down on the rail flange.

No. 257572; date, May 9, 1882; Levi Haas.—A cross-tie consisting of two cast-iron bed-plates, with bearing-blocks to which the rails are bolted. A tie-bar connects the two bed-plates. See Nos. 247248, 282309, 315771, 389464, 406346, and 420299.

No. 259095; date, June 6, 1882; J. Clark.—Further improvements on No. 249503.

No. 259726; date, June 20, 1882; Daniel Smith.—A transverse tie-bar with wide flat ends, having lugs to hold the rail flange; but the rails have to be slipped into these chairs, there being no loose or adjustable parts. Each end rests on a wooden block of white oak, 8 inches square and 2 inches thick, which rests on a stone block.

No. 259823; date, June 20, 1882; A. L. Cubberlery.—A flat cast-iron cross-tie, with concave bottom, and dovetail grooves on top, for sliding rail fastenings into place.

No. 259891; date, June 20, 1882; J. H. Meacham.—A cross-tie of ⊥ section, with end boxes for wood blocks, to which the rails are secured by hook-bolts.

No. 260231; date, June 27, 1882; J. Parr.—A cast-iron cross-tie with fixed and movable lugs for the flanges of the rails. (See No. 277333.)

No. 260724; date, July 4, 1882; A. L. Withers, jr.—Each rail rests in a groove on a metal block; the blocks have dovetailed recesses for rail-clamps and tie-bars.

No. 263078; date, August 22, 1882; Francis Tunica.—The rails rest in T shaped chairs, secured to circular blocks of metal resting on a concrete base. Each block has two tie-rods, which run not to the opposite block, but to the blocks to the right and left of the opposite block; so that the rods form horizontal triangular bracing or trussing.

No. 263919; date, September 5, 1882; C. F. Kreuz.—A cross-tie of H section, the rails resting on the web and secured by wedges. An improvement on No. 251251.

No. 265543; date, October 3, 1882; E. D. Samain.—A flat tie-bar with lugs on the ends, and a bolted plate with lugs to hold the inner side of the rail flange.

No. 265760; date, October 10, 1882; M. I. Cortright.—A cross-tie with two grooves or corrugations in its length, and with notches to receive the flange of the rails.

No. 267930; date, November 21, 1882; G. L. Putnam.—A cross-tie of square-section, hollow or solid, with hooked spikes put in place from the bottom and tapering upwards. (See No. 285842.)

No. 269442; date, December 19, 1882; R. B. Meeker.—Cross-ties of T section, with broad table. Flat horizontal bars with turned up ends, used alternately with the ties. The rail to be of extra height, bolted to chairs.

No. 270637; date, January 16, 1883; J. Clark.—A flat cross-tie with arched bearing-plates and chairs. (See No. 249503.)

No. 272477; date, February 20, 1883; Henry Reese.—A cross-tie of inverted trough sections, having flaring sides and a middle interior rib; carries longitudinal plates of similar section to which the rails are secured by gibs. The gibs are held in place by a horizontal screw and nut placed between the gib and counter-gib. (See No. 163254.)

No. 272850; date, February 27, 1883; T. Breen.—A flat cross-tie, twisted spirally in the middle and having the ends turned up. (See No. 245440.)

No. 274309; date, March 20, 1883; W. H. Gibbs and George Snook.—A cross-tie of ⊥ section, with supports for a rail-chair of inverted trough sections, with a wooden block, to which the rail is secured by hooked clamps.

No. 276414; date, April 24, 1883; E. B. Hungerford.—A cross tie of shallow channel section ⊔. The flanges are cut away and notched to hold the rail-flange, and the rail rests on a loose bed-plate with a clip to hold the other flange; the plate being held in place by a horizontal key driven through holes in the tie-flanges.

No. 277000; date, May 8, 1883; T. J. Bronson and A. Armstrong.—The rails rest in grooves on separate blocks, and are held together and in place by tie-bars and bolted clamps. (See No. 289806.)

No. 277333; date, May 8, 1883; J. Parr.—A hollow cast-iron cross-tie. The rails are secured to loose chairs having long projections which run nearly through the tie and are secured by a vertical bolt at the middle of the tie. (See No. 260231.)

No. 279280; date, June 12, 1883; Fridolf Schaumann (England).—Concrete blocks with prepared cork tie-plates. Chairs are secured by bolts; or flange rails resting direct on the cork plates are secured by clamps held by bolts passing through the concrete block.

No. 280110; date, June 26, 1883; S. B. Wright.—A cross-tie of inverted trough section, with the inside of the top arched. (See No. 298539.)

No. 280200; date, June 26, 1883; J. Mahoney and D. W. Shockley.—A cross-tie of ⊥⊥ section, with wooden bearing blocks. (See No. 370634.)

No. 281806; date, July 24, 1883; A. R. Spaulding.—A cross-tie of channel section ⊓, to which the rail is fastened by a series of flat horizontal keys or wedges in dove-tailed grooves.

No. 282309; date, July 31, 1883; Levi Haas.—Heavy cast-iron chairs, connected by tie-bars. (See No. 247248.)

No. 283076; date, August 14, 1883; J. L. Chapman.—Cross-ties of shallow channel ⊔, or of two flat plates, one above the other, separated by distance-blocks. Each rail is secured by bolted clips to a bed-plate.

No. 283230; date, August 14, 1883; H. F. Flickinger.—A cross-tie of I section, to which the rails are secured by ∩ bolts, with the nuts on the under side of the top flange of the tie.

No. 284157; date, August 28, 1883; J. W. Young.—A hollow open-sided, elastic cross-tie of ⊐ section; to be filled with ballast or earth on surface lines. Two or more of these plates to be placed inside one another, with one side open, or to form a closed tie. It is claimed to be adapted to elevated roads.

No. 285833; date, October 2, 1883; John Newton.—Channel-iron stringers ⊓ with flat cross-ties fastened to the top.

No. 285842; date, October 2, 1883; George L. Putnam.—A cross-tie of T section, depressed in the middle to hold a water trough for supplying locomotives. The rails are secured by bolted clips. (See No. 267930.)

No. 285986; date, October 2, 1883; Clark Fisher.—A bent plate cross-tie of U section in the middle with flat ends. A U bolt passes under the rail, and washers are screwed down on the rail-flange by the nuts.

No. 286651; date, October 16, 1883; E. L. Taylor.—Separate rail bearers or bowls connected by tie-bars. Lugs or clamps on the bowl hold the inner flange of the rail, and a lug on the end of the tie-bar holds the outer flange. (See report "United States.") Wooden or stone blocks may be used. (See No. 371993 and No. 382470.)

No. 287418; date, October 30, 1883; J. J. Clarke (of Peru).—A flat plate tie for portable railway track, with special joint fastenings. (Assigned to A. W. Colwell, New York.)

No. 289806; date, December 11, 1883; T. J. Bronson and A. Armstrong.—An iron or steel cross-tie of approximately semi-cylindrical section ∩, with lugs struck up by means of dies. (See No. 277000.)

No. 290793; date, December 25, 1883; L. O. Orton.—A flat inverted trough cross-tie, with wedge-shaped boxes projecting above and below to hold the bearing blocks and fastenings.

No. 291514; date, January 8, 1884; H. R. Holbrook.—A hollow cross-tie of oval section with thickened portions under the rails; rails secured by bolted clips.

No. 291523; date, January 8, 1884; John G. Krichbaum.—Large, deep castings connected by tie-bars; rails held by bolted clamps.

No. 292421; date, January 22, 1884; J. J. Du Bois.—A cross-tie with dove-tailed groove for rail and a wedge fastening.

No. 293194; date, February 5, 1884; J. Keven.—A flat tie-bar to keep rails from spreading; one end bent up to hold rail, the other end having thread and nut with movable clamp.

No. 293302; date, February 12, 1884; George W. Bloodgood.—Bolted clips for fastening rails to ties of inverted-trough section.

No. 294191; date, February 26, 1884; T. Breen.—A cross-tie made in two pieces, lengthwise; placed side by side, holding the rail chairs and fastenings between them. (See No. 245440.)

No. 296725; date, April 15, 1884; W. T. Carter.—A hollow cross-tie, with flat top and bottom and concave sides.

No. 298539; date, May 13, 1884; S. B. Wright.—Fastening rails to inverted cross-ties by clips and T-headed bolts. (See No. 280110.)

No. 299345; date, May 27, 1884; Joseph Chater (India).—Cast-iron plates with jaws forming a rail chair; the plates are connected by tie-bars. The general design is similar to that of the Denham and Olpherts ties, used in India. (Patented in India, December 8, 1883; England, January 8, 1884; France, February 1, 1884; Germany, February 7, 1884.)

No. 299557; date June 3, 1884; J. Lockhart.—A clamp or tie-rod, to be used in connection with wooden ties. A tie rod, running across the track, has clamps to hold the rail flanges, the inner clamps being held by set-screws. It is claimed that soft wood ties can be used, as there will be no tendency for the rails to spread. (See No. 327285.)

No. 302664; date, July 29, 1884; Joseph Monier (France).—A metal skeleton or framework covered with concrete, artificial stone, etc.

No. 302965 and No. 302966; date, August 5, 1884; C. S. Westbrook.—A cross-tie of ┌──┐ section, with parts of the horizontal table cut away. The rails are held by riveted and keyed angle-plates.

Nos. 10504 and 10505 (re-issues); date, August 5, 1884; J. Clark.—Improvements in No. 249503.

No. 303373; date, August 12, 1884; E. G. Holtham (of England).—Patented in England December 22, 1883.—Broad longitudinals under each rail, with transverse tie-rods, and with additional side plates to increase the bearing on the ballast.

No. 303540; date, August 12, 1884; W. G. Olpherts (India).—The tie consists of cast-iron plates connected by a tie-bar. The rails are held by jaws secured by cotters driven through the plate, tie-bar, and jaw. Patented in India, July 24, 1877; England, February 17, 1879. (See report "India.")

No. 304622; date, September 22, 1884; Charles H. Denham (India).—Somewhat similar to No. 303540, but having the rail or chair bolted to a wooden block. Patented in India, November 6, 1876; England, June 28, 1877. (See report "India.")

No. 304746; date, September 9, 1884; G. W. B. Neal.—A cross-tie made of triangular section, with the rails carried in and bolted to chairs fastened to the apex of the tie.

No. 305156; date, September 16, 1884; A. N. D. Delffs.—A concrete tie, with wooden blocks to which the rails are spiked.

No. 306090; date, October 7, 1884; Robert Moffly.—A cross-tie made of three pieces the full length of the tie, bolted together so as to form a ⊥-slot along it, in which the rail fastenings slide.

No. 306139; date, October 7, 1884; B. W. De Courcy.—A cross-tie of __/‾__/‾__ section, with the rails resting on the top, and secured by hooked clamps bolted together below the rail.

No. 309428; date, December 16, 1884; J. H. Williams.—A cross-tie of U-section, with wooden blocks to which the rails are spiked.

No. 310269; date, January 6, 1885; Abraham Gottlieb.—A cross-tie of inverted trough section, with a groove along its top table. The rail is fastened by bolted clips or a special form of locking plate or chair.

No. 310794; date, January 13, 1885; John K. Clark.—Each tie consists of two ⊥ (tee) shaped supports, with triangular wings; the supports are connected by a tie-rod. (See Nos. 323275, 350478, and 362608.)

No. 310878; date, January 20, 1885; John T. Campbell.—Metal longitudinals, with ribs on top forming a channel for the web of a flangeless T-rail. Transverse tie bars.

No. 312566; date, February 17, 1885; W. H. Knowlton.—Cross-ties of different sections.

No. 312717; date, February 27, 1885; E. N. Higley.—A flat cross-tie, with sides and ends turned down and with a vertical rib along the middle. This rib cut away for the rails, which are fastened by bolted clips. General section thus ⌒. (See Nos. 334228 and 353028.) Manufactured by the International Railway Tie Company, of New York. (See report, "United States.")

No. 312881; date, February 24, 1885; W. McVey.—A metal cross-tie in two pieces, mortised together at the middle and secured by a bolt.

No. 313072; date, March 3, 1885; A. A. Harrison.—A combined flat longitudinal and cross-tie; the cross-tie having plate at right angles, and being laid so that these plates of adjacent ties meet.

No. 313260; date, March 3,1885; L. O. Vanderbilt and M. E. Company.—Each tie consists of a pair of hollow inverted bowls, connected by a tie-bar. The rails are held by bolted clamps.

No. 313512; date, March 10, 1885; A. J. Moxham.—Cross-ties of inverted trough section, with riveted angle-irons on top, to which rail (principally girder street rails) are bolted or riveted. (See Nos. 319010 and 355778.)

No. 313778; date, March 10, 1885; C. M. Seltzer and O. T. Moock.—For street railways. Improvements in rail fastenings and stringers.

No. 314158; date, March 17, 1885; C. M. Van Orman.—A cross-tie of semi-circular section ⌒ with a cast-iron saddle at each end; the saddle has a lug fitting into a hole in the tie and two diagonal holes for rail spikes.

No. 314757; date, March 31, 1885; C. H. Van Orden.—A cross-tie of T section, with a rail chair at each end, the rails being secured by bolts which have hooked ends passing through the top of the tie.

No. 315047; date, April 7, 1885; M. A. Martindale.—Longitudinals of inverted trough section, with rails forming a part of or bolted to the top table. Connected by transverse tie-plates. Claimed to be adapted for laying along highways.

No. 315771; date, April 14, 1885; L. Haas.—A cross-tie made of two pieces the full length of the tie, with the section of figure 1, having wooden bearing blocks, to which the rails are spiked. (See No. 247248.)

No. 317244; date May 5, 1885; H. Thielsen.—A cross-tie of T section, the sides of the top table being turned down. (See No. 242850.)

No. 317763; date, May 12, 1885; M. A. Glynn (of Cuba).—Cross-ties of ⎍ or T section; also longitudinals of inverted trough section.

No. 317988; date, May 19, 1885; T. H. Gibbon.—Longitudinals with short spaces between them and connected by transverse tie-bars. The rails are held by clamps and lugs. (See Nos. 320869 and 347236.)

No. 319010; date, June 2, 1885; A. J. Moxham.—A cross-tie made of two angle-irons, with distance plates at the ends and middle ┌ ┐; the rails are bolted to high chairs. The tie is intended for street railways, and is shown with a center-bearing girder-rail. (See No. 313512.)

No. 319813; date, June 9, 1885; G. C. H. Hasskarl—A hollow box cross-tie, with a Y-shaped web inside; the small middle space receiving the T-heads of the track-bolts. It is also to be used as a longitudinal sleeper for street railways, the two large side spaces being used as conduits for telegraph wires, etc.

No. 320231; date, June 16, 1885; E. D. Dougherty and George B. Bryant.—A cross-tie of rectangular section, with an opening in the top table to receive a smaller cross-tie to which the rails are fastened, and which rests on springs placed in the larger box.

No. 320869; date, June 23, 1885; Thomas H. Gibbon.—A modification of former patent; adapted for street railways. (See Nos. 317988, 347236, 363513, 403465.)

No. 322621; date, July 14, 1885; Petherick Davey.—A tie composed of two plates and chairs connected by a tie-bar. The rails are held by keyed clamps.

No. 323275; date, July 28, 1885; John K. Clark.—Separate rail supports of T form, connected by a broad flat tie-bar, having the ends turned up and bolted to the rail support. (See No. 310794.)

No. 323356; date, July 28, 1885; G. Murray.—A flat cross-tie thickened under the rail, and having a rib at the bottom under each rail and in the middle; the rails secured by bolted plates.

No. 323430; date, August 4, 1885; J. K. Lake.—A combined metal stringer and chair for street railways.

No. 323809; date, August 4, 1885; William B. Henning.—A longitudinal plate lies under each rail; with cross-ties having deep ends, with T slots to receive the web and flange of the rails. (See No. 376884.)

No. 325020; date, August 25, 1885; R. R. Shepard.—A cross-tie of channel section ┌─┐ with one outer and one inner lug for each rail, and two ┌─ slots for clips of ⊏ shape with eccentric heads.

No. 326874; date, September 22, 1885; P. Kirk (of England).—A cross-tie with increased thickness at the rail seats, and with two lugs or clips punched up to hold the flange of each rail; the rail being secured by a wedge driven between the flange and one of the lugs (patented in England, France, Belgium, and Spain in 1885).

No. 327285; date, September 29, 1885; J. Lockhart.—An improvement upon No. 299557.

No. 327667; date, October 6, 1885; P. H. Dudley.—Separate rail supports connected by tie-bars. Each support consists of a hollow rectangular box, open on top, set on a wide rectangular base or bowl. The box has a partial filling of sand, upon which rests a block of compressed wood or wood-pulp; the rail rests on this block and is secured by bolted clamps. The heads of the bolts are inside the bowl. One object is to enable the rails to be raised or "shimmed" without disturbing the ballast. At the joints the bowl is long enough to carry two or three "boxes," according to whether the rail-joint is suspended or supported.

Nos. 327745 and 327843; date, October 6, 1885; L. E. Whipple.—A cross-tie of X section, made of two curved plates placed back to back and having flat plate across top and bottom.

No. 328632; date, October 20, 1885; J. S. Ammon.—A cross-tie of Λ section with rail chairs secured to the top ridge.

No. 329429; date, November 3, 1885; G. E. Baldwin.—A pair of rail chairs of ⎍ shape, resting on wooden blocks and tied together by a rod. The top table has a groove to receive the web of a rail of T section, having no bottom flange. Intended especially for city railways.

No. 329821; date, November 3, 1885; P. Davey.—A cross-tie of channel section, to which the rails are secured by keys and Z-shaped clamps, the lower part of the latter lying inside the tie.

No. 332384; date, December 15, 1885; J. Conley.—A fastening for attaching rails to metal ties, which have lugs to hold the outer flange of rail. The fastening is a bar inside the tie, with a hook at one end projecting through a hole and holding the rail flange, while the other end is bent up against the end of the tie. (See No. 254802.)

No. 332707; date, December 22, 1885; Jacob Frysinger.—Wooden stringers are connected by metal cross-ties of I section, having the web cut away at the ends to admit the stringers. The rails are secured by bolts passing through the stringers and the flanges of the ties. (See No. 400558.)

No. 333015; date, December 22, 1885; J. Howard and E. T. Bousfield (of England).—A cross-tie of ⌒ section, with a U-shaped depression for each rail, the rail being secured with a wooden wedge. See report, "England." (These ties have been used with the English double-headed rail; patented in England.) (See No. 335523.)

No. 333480; date, December 29, 1885; L. B. Prindle.—A steel cross-tie three-eighths to 1 inch thick; channel section ⊓; at each end is a slot to receive a tenon at the bottom of a rail chair.

No. 334228; date, January 12, 1886; E. N. Higley.—An improvement on No. 312717.

No. 334696; date, January 19, 1886; H. L. De Zeng.—An improvement in fastenings. (See No. 145991.)

No. 335523; date, February 2, 1886; J. Howard and E. T. Bousfield (of England).—A cross-tie made of a metal sheet or plate, with one or more corrugations lengthwise, the rails being held in chairs made by cutting away the corrugations. (See No. 333015.)

Nos. 335804 and 335805; date, February 9, 1886; E. P. J. Freeman.—A cross-tie made of a sheet of metal bent to form a rectangular box. A wooden block is placed inside under each rail, and a spike is driven into the wood through a hole in the metal. The spike may be split so as to flare like Λ when driven in combination, a guard-rail of a plate bent to Z shape, the rail lying on the bottom flange and all fastened to the tie.

No. 338057; date, March 16, 1886; J. Gearon.—A continuous road-bed made of channel cross-ties placed alternately ⊓ and ⊔, with the vertical flanges overlapping one another.

No. 339275; date, April 6, 1886; J. De Mott.—A cross-tie with a rail chair at each end. The end of the tie is rounded on plan, and is embraced by a ⊂ clamp with the ends turned up to hold the rail flange.

No. 339938; date, April 13, 1886; F. F. Scott.—A cross-tie with a chair for each rail; one-half of chair fixed, the other fastened by bolts. Pins driven through the web of the rail prevent vertical movement.

No. 340118; date, April 20, 1886; H. Howard.—A deep channel ⊔ cross-tie for street railways. The rails are keyed to chairs resting on the top of the flanges.

No. 341286; date, May 4, 1886; James Smith.—Bowls of V section, connected by tie-bars. The rails lie inside the bowls.

No. 341416; date, May 4, 1886; F. V. Greene.—For street railways. A continuous cast-iron hollow bearing (preferably 10 feet long and weighing 140 pounds per yard) under each rail. The rails are grooved, and are screwed to the top of the longitudinal.

No. 342987; date, June 1, 1886; A. N. Warner and T. J. Deakin.—A cross-tie of channel section ⊔ with T-shaped rail chairs fitting into it. The rail secured to chairs by bolts with hooked ends, the nuts being under the flange of the chair.

No. 344011; date, June 22, 1886; C. H. Sayre.—Flat or arched ⌒ cross-ties with pieces punched out of the top and bent to embrace the flange and web of the rail.

No. 344185; date, June 22, 1886; W. Kilpatrick.—A cross-tie of ◡ section with a slot along the flat top to receive the bottom of the rail chairs.

No. 344826; date, July 6, 1886; I. F. Good.—A flat cross-tie thickened and widened at the ends to form rail chairs, and having flanges projecting down under the chairs. The rails secured by keys.

No. 345054; date, July 6, 1886; Samuel Hyman.—Hollow columns, with caps forming rail-seats. For street railways.

No. 345733; date, July 20, 1886; C. Sailliez.—A cross-tie of channel section ⊓, with lugs to hold the rail flanges. The flanges are cut away at the ends to allow of wooden stringers being used under the rails.

No. 346998; date, August 10, 1886; D. Kaufman.—Flat cross-ties with chairs at the ends, and longitudinal continuous flat plates beyond the chairs. The space between the rails is covered by a continuous arched plate.

No. 347236; date, August 10, 1886; Thomas Gibbon.—Hollow inverted trough stringers. For street railways. (See No. 317988.)

No. 348877; date, September 7, 1886; Henry P. Adams.—Each tie consists of two rectangular plates, connected by a tie-bar. Alternate ties have lugs on the outer and inner sides of the rails. (See No. 361199.)

No. 349524; date, September 21, 1886; E. Schmidt (of Prussia).—A cross-tie made of two old flange rails laid flat, head to head, forming a tie of H H section. The rails rest on the web and are fastened by bolted clips. (Patented in Germany.)

No. 349846; date, September 28, 1886; Edward Jones.—Hollow iron boxes, with high raised seats for the rails, and connected by deep plates set on edge.

No. 350478; date, October 12, 1886; John K. Clark.—Separate rail-supports, connected by flat tie-bars. (See No. 310794.)

No. 350692; date, October 12, 1886; T. L. Mumford and H. Moore.—A cross-tie of inverted trough section, wider at the ends, with fixed lugs and movable clamps for fastening the rails.

No. 351002; date, October 19, 1886; A. T. Stevens.—A hollow rectangular box tie, with bottom flanges at the ends, and the top flanges along the sides; the rail clamps are bent to take hold of these flanges.

Nos. 351498 and 351499; date, October 26, 1886; E. C. Davis.—A cross-tie made of two old rails placed side by side. Each track rail rests on a bearing-block in two pieces, with a lip at the end to engage the rail flange. The blocks are slid into place between the tie rails and bolted through the tie.

No. 351996; date November 2, 1886; Charles Netter.—Cross-ties of ⊔ section, with hook bolt fastenings; the hook of the bolt fits into a hole in the side of the tie, and the nut is screwed down on a rail clamp. (See No. 372864.)

No. 352002; date, November 2, 1886; E. F. Reynolds.—A cross-tie of ⋀⋀ section. The rails rest in notches cut in the top, and are held by hinged clips and locking clips.

No. 353028; date, November 23, 1886; E. N. Higley.—Improvements upon Nos. 334228 and 312717.

No. 353691; date, December 7, 1886; S. D. Locke.—A channel cross-tie ⊓, with inclined ends and a transverse rib in the middle. The rails are fastened by bolted clips. (See No. 356002.)

No. 354147; date, December 14, 1886; F. G. Johnson.—Cross-ties of ⊓ section, with the bottom edges turned in to retain a concrete filling or a filling made of loose stone with melted iron poured over it, the casting being done inside the tie. The rails are held by bolted clamps; the clamp having lugs which fit into the holes in the ties, and these lugs as well as the bolts are long enough to enable the rail to be shimmed up when necessary. The shims extending under the rails and clamps.

No. 354250; date, December 14, 1886; R. S. Sea.—A cross-tie of T section with enlarged ends forming rail chairs. (See No. 375005.)

No. 354433; date, December 14, 1886; R. Morrell.—A cross-tie made of a plate bent to form a hollow rectangular box, with the top and bottom cut away at the middle. The rails are fastened to wooden bearing-blocks placed inside the tie. (See No. 365932.)

No. 355778; date, January 11, 1887; A. J. Moxham.—For street railways. A steel plate, 24 inches long 6 inches wide and one-fourth inch thick, is twisted spirally, and is embedded in concrete. Angle-irons are riveted to the top to form a rail-seat, and the two columns are connected by a tie-bar. (See No. 313512.)

No. 356002; date, January 11, 1887; S. D. Locke.—An improvement on No. 353691.

No. 357301; date, February 8, 1887; J. J. Anderson.—Metal chairs with one fixed jaw, and one loose jaw for supporting the rails. Adapted for street railways.

No. 358144; date, February 22, 1887; J. Clark.—A cross-tie of channel section, with chairs for the rails. (See No. 249503.)

No. 358981; date, March 8, 1887; J. C. Lane.—An iron bridle-rod, made in two pieces, bolted together at the middle, to prevent rails from spreading at the curves.

No. 359115 and No. 359117; date March 8, 1887; W. Wharton, jr.—A cross-tie of ⊥ or L section, with the bottom flange bent up to make a chair for the rails. To be used on street railways with girder rails.

No. 359440; date, March 15, 1887; T. Gleason.—A cross-tie of trough section ⊔, with interior cross-pieces or webs to which the rail clamps are fastened.

No. 359854; date, March 22, 1887; Henry C. Draper.—A compound tie, consisting of two channel irons placed back to back with a wooden tie between them. The three pieces are bolted together, and one end of the bolt is bent up and over so as to hold the rail flange.

No. 360397; date March 29, 1887; M. Y. Thompson.—A flat cross-tie, with a U-shaped depression at each end to receive a wooden bearing-block. The rails are fastened by keys.

No. 361199; date, April 12, 1887; H. P. Adams.—A cross-tie of T section, with chairs keyed to it. (See No. 348877.)

No. 361330; date, April 19, 1887; P. J. Severac (of Paris).—A cross-tie of I section, with the horizontal flanges bent at the ends. In some cases a broad plate is riveted to the bottom flange. The rails are fastened by clips or keyed to chairs. (This system is in use in Europe.) Patented in France, Belgium, England, Italy, and Spain, in 1884–'85. (See Report: "Belgium.")

No. 382608; date, May 10, 1887; John K. Clark.—A cross-tie consisting of two rail bearers or bowls, connected by a tie-bar. The rails are held by bolted clamps. (See No. 310794.)

Nos. 362786 and 362787; date, May 10, 1887; J. Riley (of Scotland).—A cross-tie of inverted trough section, with the rail chairs stamped or pressed by dies, the rails being secured by wedges. (Patented in England and Belgium; 1885–'86.)

No. 363020; date, May 17, 1887; L. Taylor.—A hollow box cross-tie, with outward-flaring sides and concave bottom. The rails are fastened by hook bolts with the nuts inside the tie.

No. 363513; date, May 24, 1887; Edgar S. Fassett.—Hollow inverted trough stringers, connected by tie-bars which maintain the gauge. For street railways. Improvements on the Gibson patents. (See Nos. 317988, 320869, and 347236.)

No. 365169; date, June 21, 1887; George de Beaulieu.—Two rail-bearers connected by a tie-rod. Each rail-bearer has one fixed jaw and one bolted jaw to support the rail.

No. 365350; date, June 21, 1887; A. Roelofs.—A cross-tie of channel ⊓ or inverted trough section. The rails are fastened by fixed lugs on the outside, and a tie-bar which is sprung into place on the inside. Also a flat tie with a rib under each ail and a slot along the middle for the bent tie-bar.

No. 365511; date, June 28, 1887; F. X. Georget.—A cross-tie or longitudinal, of channel section ⊔, built up of a base plate and two concave side plates with the tops flanged outward horizontally. The ties or longitudinals are connected by tie rods. (See No. 381125.)

Nos. 365932 and 365933; date, July 5, 1887; R. Morrell.—A hollow cross-tie, made of a plate bent to an oblong section, with straps around it at the rail fastenings. The metal is cut away to let the rails rest on a wood block inside the tie; the metal straps keep the spikes from working loose and allowing the rails to spread. Also a tie for elevated roads, made of two plates on edge, fastened together at the middle, and flaring apart to admit wooden bearing-blocks between them. (See No. 354433.)

No. 366546; date, July 12, 1887; N. S. White.—A cross-tie of channel ⊓ or inverted trough section, with a base plate at each end, with a bearing-block of wood or other material inside under each rail. The rails are fastened by locking clamps.

No. 367325; date, July 26, 1887; John Splane.—A cross-tie of ⊓ channel section, with the bottom of the sides flanged outwards. The rails are let into apertures in the top and rest on the hooked ends of two tie-bolts, the inner ends of which are connected by a turnbuckle which is tightened by a wrench, there being a hole in the middle of the top table of the ties.

No. 367383; date, August 2, 1887; J. Fitzgerald.—The rails are fastened to a cast-iron cross-tie by hook-headed spikes, which are secured by horizontal keys fitting into corresponding notches in the tie and spike.

No. 369591; date, September 6, 1887; J. H. Coffman.—A solid tie with a groove along the top and lugs for the inner flanges of the rail; hooked rods hold the outer flange, and the inner ends of the rods are attached to a spring at the middle of the tie.

Nos. 369755 and 369756; date, September 13, 1887; William L. Van Harlingen, sr.—A box cross-tie made of an inverted trough fastened to a base-plate; inclined and closed ends. It incloses a wooden tie or wooden bearing-blocks. The rail is fastened by wood screws with wide heads. Also a metal tie with end boxes to contain springs on which the rails rest.

No. 370072; date, September 20, 1887; R. C. Lukens.—A cross-tie of T section, with slots in the web for attaching weights or anchors to keep the track in position. The rails are fastened by lugs and bolts.

No. 370164; date, September 20, 1887; H. L. Stillman.—A street-railway track, with wooden stringers connected by metal tie-bars of I section, secured by keys.

No. 370192; date, September 20, 1887; D. C. Heller.—A hollow box-tie of rectangular section, with the top cut away under the rails. The tie is filled with concrete and has two wooden blocks to which the rails are spiked.

No. 370226; date, September 20, 1887; C. W. Yost.—A flat tie with lugs, and a separate bed-plate, with lugs, for each rail.

No. 370,634; date, September 27, 1887; J. Mahoney and D. W. Shockley.—A cross-tie of _┴_┴_ section, with a saddle plate for each rail seat. The plate has a lug for one flange and a clip is bolted on the other. (See No. 280200.)

No. 370837; date, October 4, 1887; John B. Williams.—The tie consists of two rectangular iron frames or boxes connected by a tie-bar; lugs or two of the sides form a seat for the rail. A block of wood or other material is fitted into the frame and has to this the rail is spiked.

No. 371110; date, October 4, 1887; W. H. Troxell.—A cross-tie with raised rail seat and outer lugs. Hooked bolts, with nuts on the outer side of the chair, hold the inner flange of the rail.

No. 371780; October 18, 1887; J. Moser and E. Moeckel.—A cross-tie of T section, with a chair at each end; each chair has an inclined rail-brace and two hook-bolts.

No. 371993; date, October 25, 1887; Enoch L. Taylor.—Two rail-bearers of inverted trough section, connected by a flat tie-bar, placed on edge, which passes through a slot in each rail-bearer or bowl. Lugs on the bearers hold the inner side of the rail flange, and lugs on the ends of the tie-bars hold the outer side. (See No. 286651; see Report; "United States.")

No. 372,230; date, October 25, 1887; A. McKenney.—Cross-ties of channel ┌─┐ section, with one end cut off at an angle to allow of a diagonal tie to the next transverse tie, each set of three ties making a letter N on plan. Arranged continuously.

No. 372525; date, November 1, 1887; J. A. Dunning.—A hollow rectangular cross-tie, with open inclined ends; bottom and sides have corrugations, transversely and vertically. Bolted clip fastenings.

No. 372703; date, November 8, 1887; I. A. Perry.—A cross-tie made of two old rails, with saddle chairs fitting over the heads of these rails. Track rails fastened by chair and sliding wedge, being held by flange and web.

No. 372864; date, November 8, 1887; C. Notter.—A cross-tie of T section, with the ends beyond the rails bent down vertically and then horizontally. Rails fastened by bolts having hooks, which take hold of the bottom of the web of the tie. (See No. 351996.)

No. 372879; date, November 8, 1887; S. H. Stull.—A cross-tie made of a plate bent to a semi-circular form ⌣, and semi-cylindrical at the ends ∪. Rails fastened by clamps. Open ends.

No. 373656; date, November 22, 1887; W. P. Hall and C. C. Barnett.—A cross-tie of semi-circular section ⌒, with open ends. Shoulders pressed out to prevent spreadings. Rails fastened to saddles or straps. (See No. 375996.)

No. 375005; date, December 20, 1887; R. Sea.—A cross-tie of channel section, with closed ends. A strengthening plate is bolted to the under side of the top table, and the side flanges are deeply notched to give elasticity. A metal block is bolted under each rail, and the rails are secured by bolted plates. (See No. 354250.)

No. 375763; date, January 3, 1888; T. B. Moore.—A cross-tie of inverted channel section ┌──┐. The rails are held by clamps and hook-bolts; the hook end is inside the tie, and the nut is screwed down on the clamp, which has a lug fitting into the bolt hole.

No. 375856; date, January 3, 1888; R. T. White.—A cross-tie of ⊥ section, with high chair at each end to receive the web of a girder rail. Intended for street railways. (See Nos. 385395 and 386420.)

No. 375996; date, January 3, 1888; W. P. Hall.—A hollow cross-tie, made of a plate bent almost cylindrical, but with the bottom open and flat on top. The rails are fastened to saddle straps. (See No. 373656.)

No. 376214; date, January 10, 1888; J. W. Smith.—A hollow rectangular cross-tie, with holes in the top to admit the rail chairs, which rest on coiled springs inside the tie.

No. 376250; date, January 10, 1888; N. M. Marks.—The two rail-bearers are of ⊥⊥ section, with ratchet teeth on the outer faces; over the upright leg fits a saddle ∩, also with ratchet teeth, so that the height of the rail can be adjusted. The rails are secured to the saddles, which are connected by flat tie-bars.

No. 376884; date, January 24, 1888; William B. Henning.—A flat bar, bent up at the ends to embrace the flange and web of rail. Loose angle clamps on inside of rail. (See No. 323809.)

No. 377162; date, January 31, 1888; G. Kelton.—A cross-tie of channel section ┌──┐, with a separate bottom, having projections on its inner side to give a hold to the pulp with which the tie is to be filled. The rails are fastened by hooked bolts, with nuts inside the tie, cavities being left in the pulp filling.

No. 378133; date, February 21, 1888; James M. Gibberson.—Stone or other blocks with flat tie-bars, having lugs which can be bent over the flanges of the rails.

No. 378280; date, February 21, 1888; F. L. Barrows.—A cross-tie of inverted trough section, with clips struck up on the outside of the rail to hold its flange, and clips lengthwise on the inside of the rail to hold a rail fastening.

No. 378930; date, March 6, 1888; J. Hill.—A flat cross-tie, corrugated lengthwise top and bottom. The rail is keyed to a chair. The inventor proposes to use a double-headed rail.

No. 379312; date, March 13, 1888; S. B. Jerome.—A hollow rectangular cross-tie, made of a bent plate. It is to be filled with straw, sawdust, etc., and has a narrow bearing-block along the underside of the top, to which the rails are spiked. The ends are closed by wood or cement blocks.

No. 379399; date, March 13, 1888; J. Jacobs.—A cross-tie of channel section └──┘ with closed ends; a top plate is bolted on by side clamps to form a rail seat. The tie is to be filled with concrete, etc.

No. 379574; date, March 20, 1888; C. P. Hawley.—A cross-tie of I section, with the top flange bent to make a rail brace. A longitudinal bridge is used under the rail at joints.

No. 379575; date, March 20, 1888; C. P. Hawley.—A combined metal and wooden tie, consisting of a metal beam of ⊥ section, resting on a wooden tie or plank.

No. 379576; date, March 20, 1888.—A cross-tie of ⊥ section, with slots for the web of a T girder, forming a rail seat, or which can be made a longitudinal bearing.

No. 379612; date, March 20, 1888; C. G. Singer.—A cross-tie of + cruciform section, with the top flange cut away at the rail seats. The rails are held by horizontal U clamps, the end being in a hole in the top flange of the tie, with the two legs resting on the rail flange. A key or plug, driven horizontally through the tie, holds the clamp down on the rail.

No. 380274; date, March 27, 1888; George E. Blaine and Edward Hill.—Anchor-blocks or bowls of terra cotta or earthenware, of frusto-conoidal or frusto-pyramidal form, connected by metal tie-bars. The rails rest on wooden plates.

No. 380623; date, April 3, 1888; H. L. De Zeng.—Improvements upon No. 145991, etc.

No. 381059; date, April 10, 1888; W. H. Donaldson.—A cross-tie of ╥╥ section. The rails are held by gibs with long ends within the tie. which are to be secured by a cotter driven through the tie parallel with the rail.

No. 381125; date, April 17, 1888; F. X. Georget.—Improvements upon No. 365511,

No. 381860; date, April 24, 1888; E. R. Stiles.—A cross-tie of channel section └──┘, with a wooden block under each rail.

No. 382134; date, May 8, 1888; W. H. Britton.—A cross-tie of T section, with the vertical web corrugated vertically. The rails are secured by lugs and clamps.

No. 382394; date, May 1, 1888; J. B. Sutherland.—A cross-tie of approximately Y section; curved like the section of a yacht, and with the top edges bent in to form horizontal flanges for the rail-chairs.

No. 382470; date, May 8, 1888; R. M. Hunter.—A modification of the Taylor patents. (See Nos. 286651 and 371993.)

No. 382855; date, May 15, 1888; F. Barhydt.—A hollow box cross-tie, with closed ends. There is a wooden block the full size of the face of the tie at the top, and another at the bottom; both inside. Coil springs are interposed between the top and bottom sections,

No. 383118; date, May 22, 1888; M. Fitzgerald.—A cross-tie of channel section ┌──┐, with solid ends. Fixed lugs and hooked spikes are the rail fastenings.

No. 384785; date, June 19, 1888; Jacob Reese.—A cross-tie of ∩ section, with a groove along its top table; rail seat bolted on top. The rail is secured by a bolt passing under it and through the chair, having Γ washers to hold the rail flange. It is to be rolled from a plate of No. 7 steel 24 inches wide; bedded in ballast.

No. 385395; date, July 3, 1888; R. T. White.—A channel cross-tie of U section, with rails secured to saddles by bolts and clips. (See No. 375856.)

No. 385492; date, July 3, 1888; D. Y. Wilson.—A cross-tie made of two angles ─┘ └─, with a base plate and channel plate for rail seat at each end. Rails bolted through top and bottom plates.

No. 386064; date, July 10, 1888; H. T. Ferris.—Rails, ties, etc., of a composition of 500 parts of paper pulp, 25 parts of silicate soda, and 10 parts of barytes.

No. 386119; date, July 17, 1888; R. W. Flower, jr., and S. L. Wiegand.—A hollow cross-tie of rectangular section, with part of the bottom cut away and turned down to prevent lateral movement. The rails are spiked to wood blocks inside the tie. (See No. 420485. See Report; "United States.")

No. 386156; date, July 17, 1888; J. A. Ogden.—A cross-tie of channel section └──┘, wide at the bottom, with bearing blocks and hook-fastenings for the rails.

Nos. 386356 and 386357; date, July 17, 1888; H. Shultzen.—A channel tie └──┘, with the middle part of the bottom cut away and turned up to prevent lateral movement. The rail is fastened to a wooden block by Z-clips and a longitudinal bolt under the rail, or by diagonal bolts. (Now being manufactured by the Standard Steel Tie Company, of New York.) (See Report; "United States.")

No. 386389; date, July 17, 1888; A. Durand.—A cross-tie of inverted trough section, with clips and channels stamped in it. (See Report; "United States.")

No. 386420; date, July 17, 1888; R. T. White.—Hollow box cross-ties of different sections, made of bent plates. Cross-section intended to give elasticity. (See 385395.)

No. 387602; date, August 7, 1888; Peter Semonin.—Cross-ties of inverted trough section. The rails are held by a fixed lug on the outer side and a gib and cotter with serrated faces on the inner side. (See No. 421769.)

No. 388266; date, August 7, 1888; George Cowdery and E. R. Thomas, (Australia).—A cross-tie of inverted cross-section, with closed ends, and with lugs stamped up at each rail seat. Each rail rests on a bed-plate placed between the lugs, and is secured by a split key. (Patented in England, June 30, 1886.) (See Report; "Australia.")

No. 388277; date, August 21, 1888; A. J. Hartford.—A flat cross-tie, with end turned up, and a bent plate tie bridge, arched in the middle, bent to form a shoulder for inner flange of rail; the rail rests on this plate and the end is turned over the outer flange and secured by a bolt through both plates. (See No. 401949.)

No. 388296; date, August 21, 1888; James R. Millhouse.—A cross-tie made of a sheet of metal, forming a deep tie-bar on edge, and bent to form a box or frame under each rail.

No. 389464; date, September 11, 1888; L. Haas.—A cross-tie of rectangular section; top cut away at ends and middle. Wooden block under each rail. (See No. 247248.)

No. 390014; date, September 25, 1888; R. P. Faddis.—Wooden stringers, with flat iron tie plates across top and under rail, with U bolts embracing the stringers. For street and steam railways. (See No. 391131 and No. 398037.)

No. 390370; date, October 2, 1888; I. G. Howell.—A cross-tie of channel section ⊓, with blocks under the rails. The top is cut away for the rail, and the rail clamps are fastened by hooks.

No. 391131; date, October 16, 1888; R. P. Faddis.—Four or more short pieces of ties in a frame with distance pieces and bolts. These sections are held together by tie-bars. (See No. 390014.)

No. 391492; date, October 23, 1888; W. J. Stifler.—A flat cross-tie with diagonal grooves on the under side near the ends to receive the heads of the bolts of the two plates, each with a lug, which form one rail seat.

No. 391704; date, October 23, 1888; L. Haas.—A cross-tie of channel section ⊔, higher at the rail seats, with notched flanges for the rails. (See No. 247248.)

No. 391999; date, October 30, 1888; A. H. Ames.—A flat cross-tie, with flaring ends of channel section ⊓, having riveted and bolted clips for rail fastenings.

No. 392849; November 13, 1888; J. Cabry and W. H. Kinch, (of England).—A rolled steel cross-tie of inverted trough section, with lugs stamped out. Rails secured by keys driven between flange and lug. (In use on the Northeastern Railway, in England.) (See report, "England.")

No. 393515; date, November 27, 1888; D. M. McRae.—A wooden or iron tie, with metal sockets at ends forming rail seats.

No. 394426; date, December 11, 1888; David Wilson, (England).—A tubular tie of concrete or other composition cast round a core of wire netting. Blocks of wood are placed inside. Patented in England, May 15, 1885, and February 17, 1886; France, March 16, 1886; Belgium, March 17, 1886; Spain, July 20, 1886.

No. 394738; date, December 18, 1888; G. W. Thompson.—A hollow cross-tie of rectangular section, with a metal bearing-block inside under each rail. Bolted clip rail fastenings.

No. 395134; date, December 25, 1888; M. Hagarty.—A cross-tie made of two channels placed back to back] [, inner lug on one, outer lug on the other. The bolt holes in vertical web are elongated to allow the channels to be shifted to let rail in.

No. 395304; date, December 25, 1888; C. F. Yarbrough.—Hollow cross-ties of rectangular section, with open ends and openings at sides. Wood blocks may be used, or the ties may be filled with ballast.

No. 395447; date, January 1, 1889; Michael Maloney.—A cross-tie of cruciform section, +. Upper web cut away at rail seats to let rails rest on horizontal web. Rail clamps bolted to upper web.

No. 396160; date, January 15, 1889; H. Hipkins, (of England).—A stamped metal cross-tie of ⌒ section, with lugs and rib stamped out of top table. (Patented in England, 1888.)

No. 396473; date, January 22, 1889; C. P. Espinasse, (of France).—A cross-tie of ⊥ section, with vertical web cut away for rail chair to which rail is secured by wooden wedge.

No. 398004; date, February 19, 1889; S. U. Smith.—A cross-tie of channel section ┌─┐, with closed ends. The rails rest on the ends of a separate cross-plate, with fixed lugs inside, and bolted plates outside.

No. 398037; date, February 19, 1889; R. P. Faddis.—Short pieces of ties connected and braced together to form a sort of crib. (See Nos. 390014 and 391131.)

No. 400558; date, April 2, 1889; Jacob Frysinger.—A cross-tie of I section in three pieces. The web is short and the flanges embrace a wooden stringer at each end, and are secured by bolts. (See No. 332707.)

No. 400643; date, April 2, 1889; H. L. De Zeng.—Cross-ties of channel section ┌─┐; with T a-iron bolted inside under each rail, forming an anchor plate. The rails are secured by bolted clamps. (See No. 145991.)

No. 401949; date, April 23, 1889; Arthur J. Hartford.—A rolled cross-tie of inverted trough section, with a longitudinal channel on the top table. Rails secured by bolts and clamps. (See Report; "United States"; see No. 388277.)

No. 402818; date, May 7, 1889; Karl L. Gocht (Germany).—A cross tie of inverted trough section, with bottom horizontal flanges. A rail chair is secured to lugs on the tie.

No. 403464; date, May 14, 1889; E. J. Devens.—A cross-tie of channel section ┌─┐. The rails are held by bent clamps, which hold the flange of the rail and the sides of the tie.

No. 403465; date, May 14, 1889; Thomas H. Gibbon.—For street railways. Stringers having one side higher than the other __┘, to fit the shape of a special side-bearing rail; the rail has a vertical web on its under side, to fit into the stringer, where it is held by the tie-bars. (See No. 317988.)

No. 403741; date, May 21, 1889; Robert Dansinger.—For street railways. Separate blocks connected by tie-bars. The rails are secured by cotters and keys.

No. 404043; date, May 28, 1889; Pierre Kolgraf (Belgium).—Cross-ties, formed of two bars of Z section, with a rail chair riveted between them at each end. The rails are held by keys driven between the rails and the lugs on the chairs. (See Report, "Belgium.") (Patented in Belgium December, 1885; France, January 5, 1886; England, March 16, 1886; Italy, July 12, 1886.)

No. 404401; date, June 4, 1889; Jacob Haish.—Cross-ties made of old rails laid head down. The track rails are to be of bridge section and secured by lugs.

No. 406129; date July 2, 1889; T. R. Dunning.—A hollow box cross-tie of rectangular section, with the top projecting beyond the sides forming flanges to which the rails are fastened. An iron block is placed inside under each rail.

No. 406346; date, July 2, 1889; Levi Haas.—A cross-tie of channel section └─┘. The rails rest in notches cut in the sides, and are secured by springs and clamps. (See No. 247248.)

No. 408255; date, August 6, 1889; C. B. Palmer.—A cross-tie of ⊥ section. The rails are held by ──┐ clamps, the lower part of which straddles the web of the tie, and is secured by a pin and split key.

No. 409860; date, August 27, 1889; A. C. Nickloy.—A cross-tie of rectangular box section, made by coiling a steel plate spirally.

No. 410176; date, September 3, 1889; John R. McCartney.—A broad shallow cross-tie of ╲▁╱ section, with horizontal flanges. The rails are secured by clips made by turning up a strip of the flange of the tie, or by bolted clamps.

No. 410236; date, September 3, 1889; A. B. Fitch.—A cross-tie of inverted trough section, similar to the Haarmann type (Germany), having a narrow upper part and wider lower part. The upper part is cut away at each rail seat to let the rail rest on the lower part. The rails are secured by dove-tailed keys or wedges driven horizontally, one side being in a notch in the tie, and the other side bearing on the rail flange.

No. 410684; date, September 10, 1889; B. W. Ellicott.—A cross-tie of channel section, └─┘, with rail chairs of ⊂ shape; the rail is bolted to the upper leg, which is prolonged so that the legs of the two chairs meet and are secured by bolts. The chairs are bolted to the tie.

No. 410933; date, September 10, 1889; Edward Samuel.—A cross-tie of I section, with the top flanges cut and bent to form lugs between which the rail flange is held and secured by keys. A flat bar or plate, as deep as the web of the ties, is laid between the the ties at the middle, parallel with the rails.

No. 411959; date, October 1, 1889; Robert Forsyth.—A cross-tie of rectangular box section, with a rib or flange under the lower side; it is made by bending a plate to the required form and riveting together, the ends turned down to form the longitudinal rib.

No. 412000; date, October 1, 1889; John M. Robbins.—Longitudinals of ─┴──┴─ section, with a continuous stringer of wood placed inside.

No. 412260; date, October 8, 1889: E. A. Jenks.—A flat tie-bar, with the ends bent up to hold the outer flange of the rails; used with a metal plate under each rail, having lugs to hold the inner side of the rail. The object is to maintain the gauge of track and prevent spreading of rails.

No. 416050; date, November 26, 1889; C. F. Z. Caracristi.—A cross-tie of I section, fitting into a chair of box shape, with concave sides at each end.

No. 416081; T. F. Thomas.—A cross-tie in two pieces, spliced at the middle by plates and bolts. The inner end of one piece has a semi-circular groove, which receives a semi-cylindrical rib on the end of the other piece; forming a horizontal hinge joint.

No. 417426; date, December 17, 1889; Richard Jones.—A cross-tie having a deep recess at each end to receive the rail up to its head; the rails are held by jaws secured by keys driven horizontally through the tie.

No. 418052; date, December 24, 1889; William Partridge and James McCutcheon, jr.—A hollow cross-tie of triangular section, laid with the apex downward. A brace of similar form is placed inside the tie under each rail. The ends are closed by blocks of preserved wood. The rails are secured by bolted clamps.

No. 418158; date, December 31, 1889; B. Boyer.—A cross-tie of cruciform section +, with the top web cut away at each rail-seat, and sloping away from the rail-seat to the middle and ends of the tie. The rails are held by angle-bar clamps and keys.

No. 419101; date, January 7, 1890; William H. Bagby.—A cross-tie of shallow channel section └─┘, with lugs on the sides to hold the inner flanges of the rails. A loose block or seat, secured by bolts, is under the rail, and has lugs for the flanges.

No. 420299; date, January 28, 1890; Levi Haas.—A cross-tie of inverted trough section. The rails are fastened by bent clamps, with the ends secured inside the tie. (See No. 247248.)

No. 420352; date, January 28, 1890; William MacManes and George E. Lum.—A cross-tie made of two plates of < section (thus <>), with a wooden block of hexagonal section at each end. Bolts pass through the plates and blocks. Between the two blocks the plates have longitudinal flanges, to form a closed bottom.

No. 420485; date, February 4, 1890; S. L. Wiegand.—A cross-tie of inverted trough or channel section, with roughened top and corrugated sides. The rails are held by hook-bolts; the hook end holds one flange, and at the other end is a nut and clamp for the other flange of the rail. (See No. 386119.)

No. 420674; date, February 4, 1890; Isaac Brown.—A cross-tie of └─┘ section, either in one piece or in two pieces bolted together at mid-length. The rails are held in chairs.

No. 420895; date, February 4, 1890; J. B. Wilson.—A cross-tie of ⊥ section, with a chair and lug for each rail. A loose clamp is put on the inner side of each rail and secured by the head of a long spike-shaped rod driven through the tie into the ground.

No. 421769; date, February 18, 1890; Peter Semomin.—Cross-ties of inverted trough or channel section, with a depression in the top at each end to form a rail seat. The rails are secured by bolted clamps. (See No. 387602.)

No. 422830; date, March 4, 1890; M. H. Pierce.—A cross-tie of ⊥ section, with a saddle-chair under each rail.

No. 423447; date, March 18, 1890; Percy W. Ross.—A cross-tie of channel section ⊔, with corrugated bottom. At both ends an angle-iron is secured on the outer side of each side. Each rail rests on a block of wood.

No. 423586; date, March 18, 1890; John M. Bailey.—A cross-tie made of a plate, bent to approximately a double tubular section ∞, of different forms. The rails are secured by bolted clamps.

No. 423852; date, March 18, 1890; Lewis Barnes.—A cross-tie of flat channel or curved section, with the ends bent to form a brace for a wooden stringer. An angle-iron is riveted to the tie at the inner side of each stringer.

Total number of patents from July, 1839, to March, 1890: 491.

Patents for cross-ties or track of concrete, clay, compositions, etc.: Nos. 127553, 130010, 186710, 251625, 279280, 302664, 305156, 380274, 386064, 394426.

Patent for glass ties: No. 211697.

TIMBERS USED FOR TIES IN SOME FOREIGN COUNTRIES.

The following notes are extracted from the correspondence of Mr. Tratman on the species of wood used in some foreign countries. Some further particulars will also be found in the special returns of the various railways in the foregoing report:

Turkey.—Smyrna and Cassaba Railway. Oak and Pine.

Egypt.—Early in 1889 the Government was negotiating for 500,000 ties from Australia; probably of jarrah wood.

India.—The principal woods used are the native säl and deodar and imported creosoted pine. It is stated that there is always a market for good wooden ties, the cost of which is not much affected by the extensive introduction of metal. They appear to be used at frogs, switches, sharp curves, bridges, etc., and one writer estimates that 6 per cent. of the mileage would still be laid with wooden ties, even if all the railways should introduce metal ties as rapidly as possible and discard wooden ties except where their use is "imperative" (?). Deodar is a soft wood, with which accurate gauge can not well be maintained, and with which the risk from fire in dry seasons is 50 per cent. more than with säl ties. Curves of 1,000 to 1,500 feet radius, laid with deodar ties, require to be respiked about every three months, and under very heavy traffic the gauge has been one-half inch wide in three months with new ties. Under similar traffic the gauge is only one-eighth to one-fourth inch wide in two years where säl is used, and remains correct under ordinary traffic. Säl wood weighs about 53 to 70 pounds per cubic foot. The best ties are of good sound Nepal säl well matured, and not cut out of small trees with a great proportion of sap-wood. The writer mentioned above states that he has tried deodar, teak, asna, iron-wood, jarrap, and red gum from Australia, English oak, creosoted fir, yellow pine, etc., and has not found any, except the oak, to approach the durability of säl, the life of which is estimated at eighteen years. The creosoted fir ties are liable to dry-rot. The Rohilkund and Kumaon Railway has tried jungle-wood, but with very unsatisfactory results. The wood answers well for buildings, but rapidly rots in the track. At the beginning of 1887 there were 70,000 in use, and in eighteen months 38,000 had been replaced with säl, while the rest were being gradually replaced. The jungle-wood was to be had for the cutting when the road was built, but though cheap it was not economical.

Ceylon.—Owing to the weight of the native woods and the difficulty of hauling to the railway, etc., it has been found to be cheaper to import ties from Europe. There seems to be a movement now, however, in favor of utilizing the native supplies or for the forest department to turn its attention to the propagation of suitable trees. At the beginning of 1889 there were 182½ miles of railway, 5 feet 6 inches gauge, laid with 72-pound flange rails. The ties are of creosoted Norway pine, buried in the ballast, to protect them from the direct heat of the sun. They are 9 feet 9 inches long, 10 inches by 5 inches section, spaced about 3 feet apart.

New Zealand.—According to the official report of Mr. J. P. Maxwell, M. Inst. C. E., general manager of the government railways, there were 1,758 miles of railway, 13 feet 6 inches gauge, in operation in March, 1888. The rails are of iron, 40 and 52 pounds per yard, and steel, weighing 52 and 53 pounds per yard. Several native timbers are used. The contract prices for wooden ties are 72 cents, or by other contracts 56 to 60 cents, hewn or sawn, for birch and black pine; 36 to 46 cents for Kamai, 46 to 52 cents for totara, 59 cents for silver pine. There are about 2,100 ties per mile or 3,518,238 in all. The renewals during the year ending March 31, 1888, were 122,027 ties.

Tasmania.—The track consists of 43-pound steel flange rails on ties of stringy bark, iron bark, blue gum, or peppermint. The ties are 6 feet 6 inches long, 9 inches wide, 4½ inches thick; laid 2,450 to the mile, 24 inches apart at joints. They are in 6 feet of bottom ballast, with 4½ inches of boxing and top ballast.

Argentine Republic.—East Argentine Railway, handerbay; Western of Buenos Ayres Railway, quebacho and urunday.

Uruguay.—Uruguay Northwestern Railway, creosoted pine.

Brazil.—Herobo and native hard woods.

Chili.—Antofagasta Railway, Chili oak; Copiapo Railway, Chili oak; Coquimbo Railway, cypress; Taltal Railway, white oak.

Peru.—Pisco and Yca Railway, California redwood.

Venezuela.—La Guaira and Caracas Railway, lignum-vitæ

United States of Colombia.—Lignum-vitæ.

Mexico.—Merida and Progreso Railway, iron-wood.

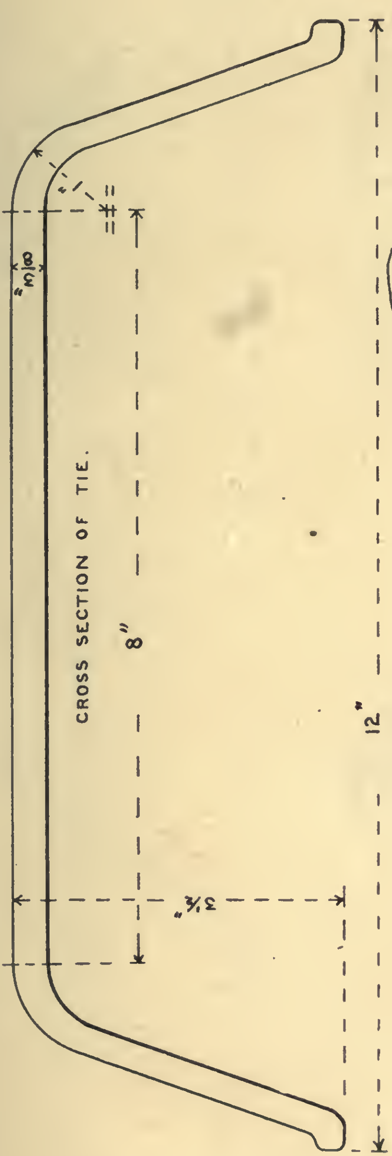
Cuba.—Jequi and native hard wood.

Hawaii.—California redwood.

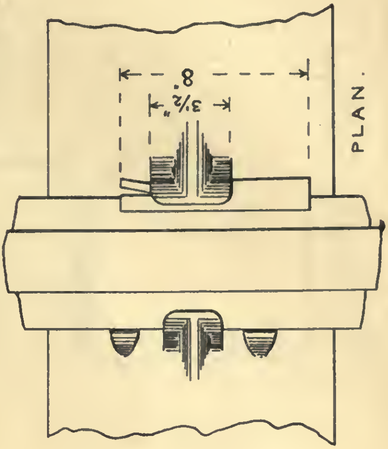
NORTHEASTERN RY.

— ENGLAND. —

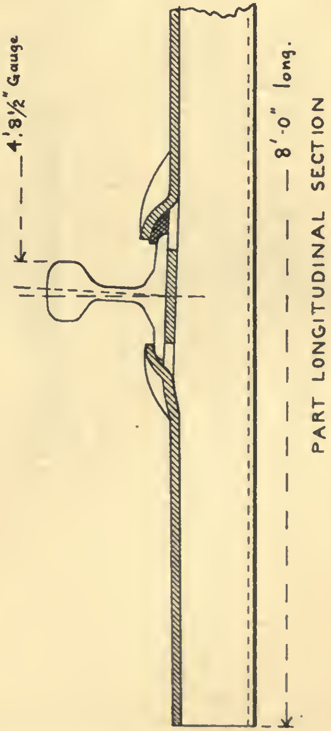
PLATE No. 1.



CROSS SECTION OF TIE.



PLAN.

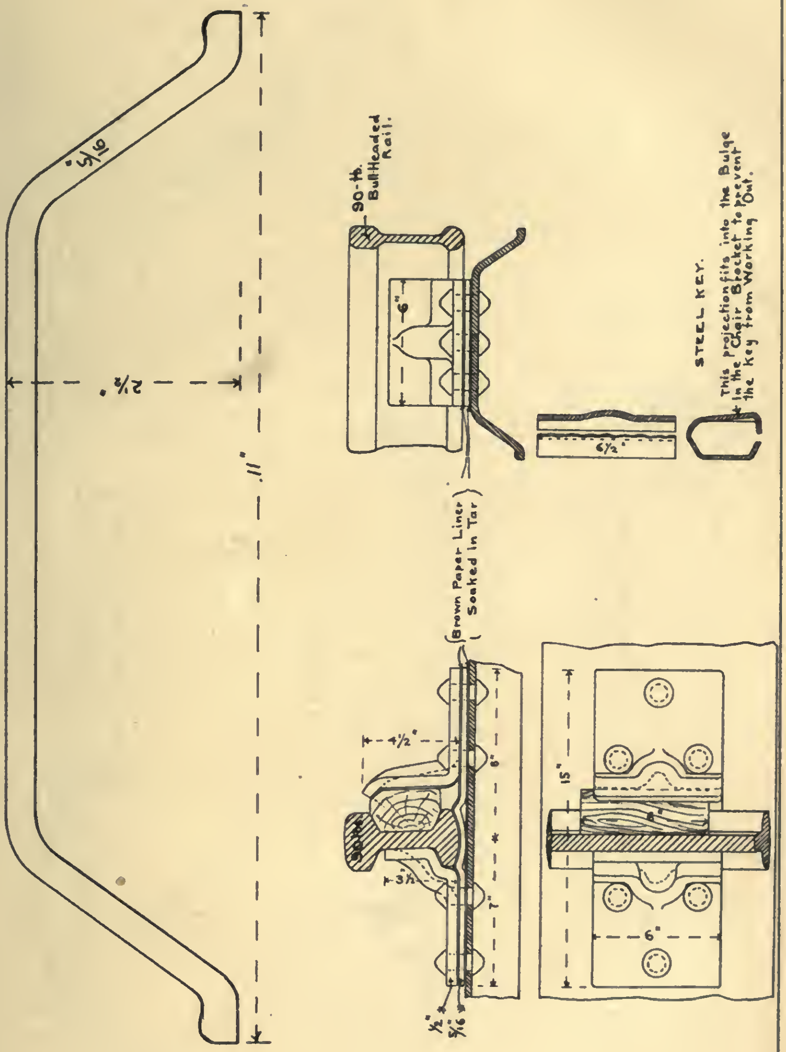


PART LONGITUDINAL SECTION

E. E. Russell Tratman.

ENGLAND. PLATE No. 2.

LONDON & NORTHWESTERN RY.

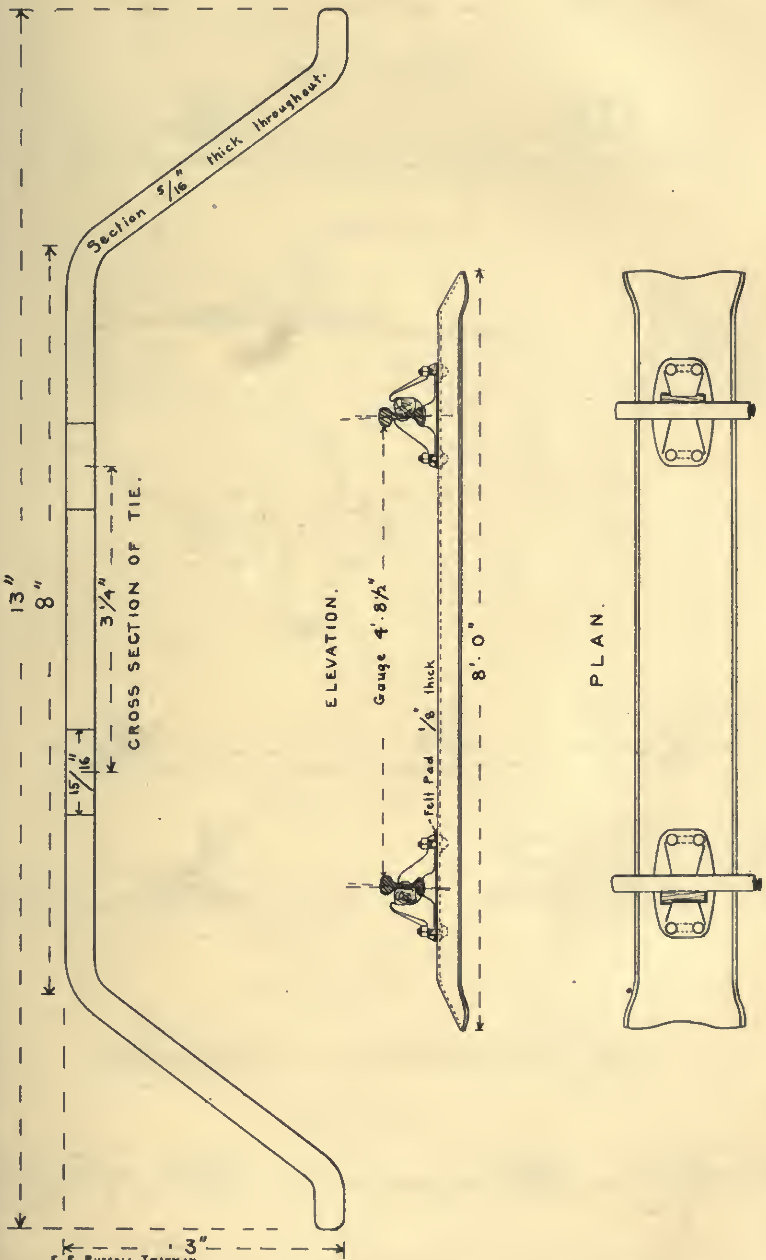

5/16"
2 1/2"
11"
90-lb. Bull-Headed Rail.
6"
Brown Paper Liner Soaked in Tar
6 1/2"
STEEL KEY.
This projection fits into the Bulge in the Chair Bracket to prevent the Key from Working Out.
4 1/2"
6"
3 1/2"
7"
1/2"
5/16"
15"
6"

E. E. RUSSELL TRATMAN.

MIDLAND RY.

— ENGLAND. —

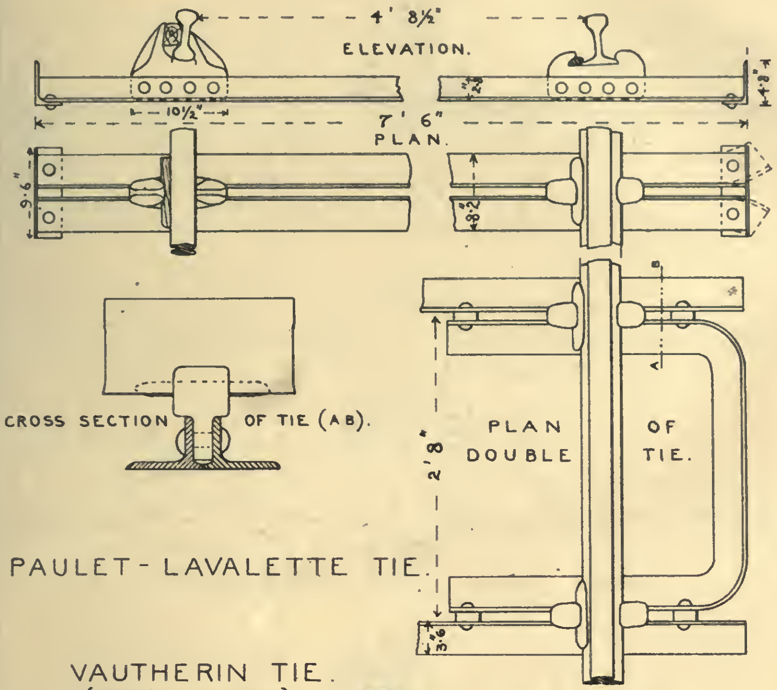
PLATE No. 3.



E. E. Russell Tratman.

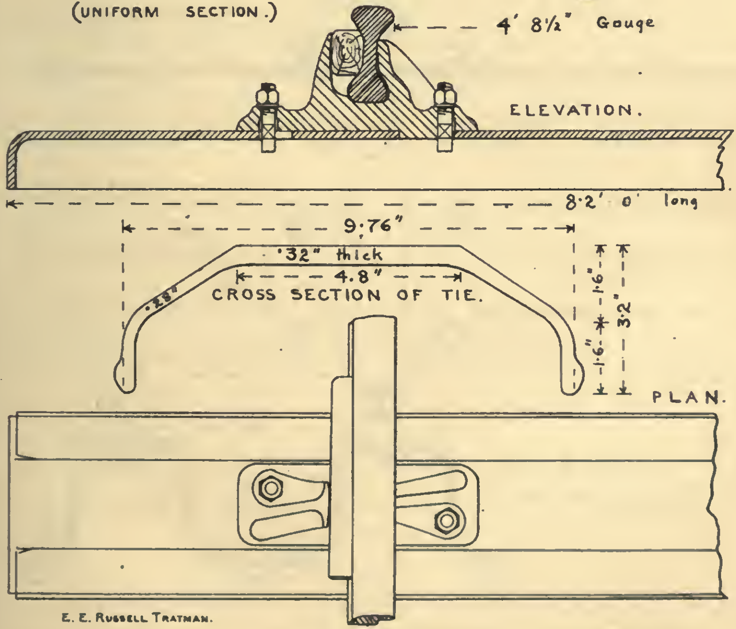
STATE RAILWAYS. PLATE No. 5.

FRANCE.



PAULET-LAVALETTE TIE.

VAUTHERIN TIE.
(UNIFORM SECTION.)

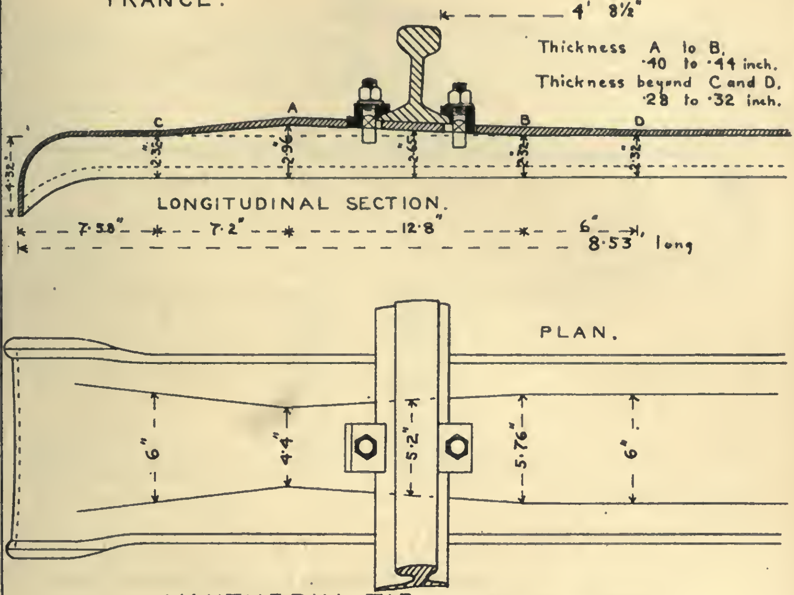


E. E. Russell Tratman.

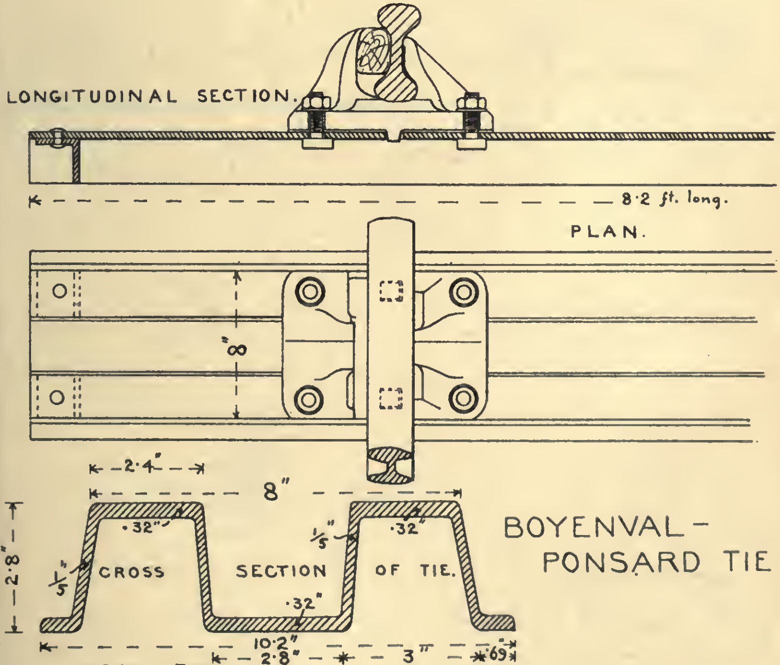
STATE RAILWAYS.

PLATE No. 6.

FRANCE.



VAUTHERIN TIE (VARYING SECTION.)



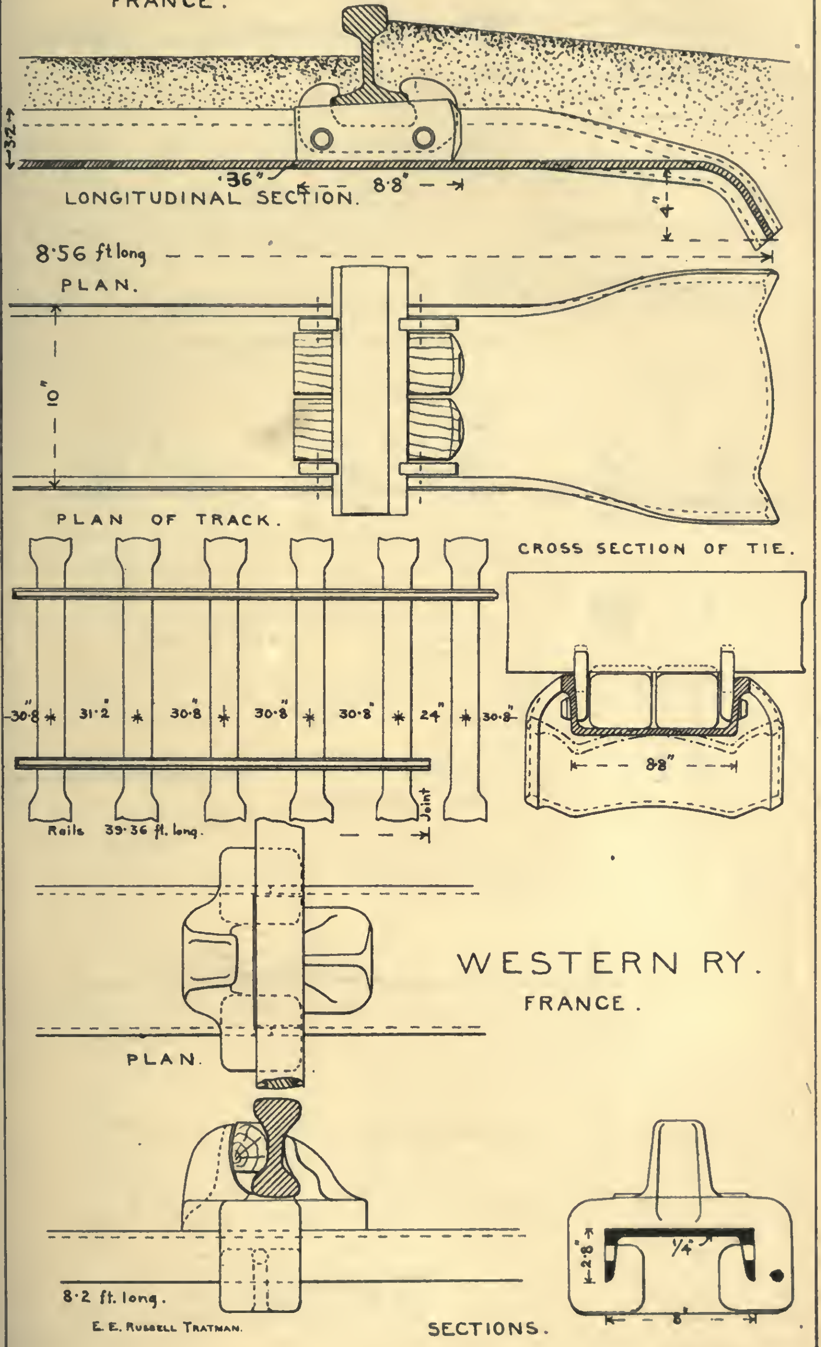
BOYENVAL-PONSARD TIE.

E. E. RUSSELL TRATMAN.

EASTERN RY.

FRANCE.

PLATE No. 7.

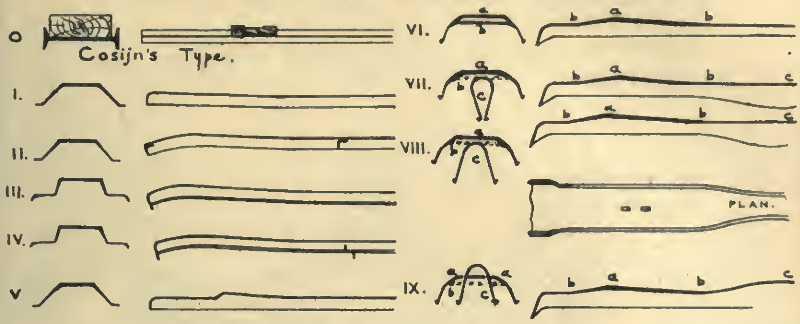


WESTERN RY.

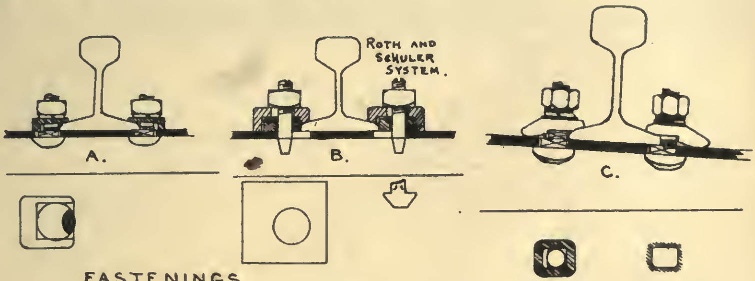
FRANCE.

HOLLAND. PLATE No. 8.

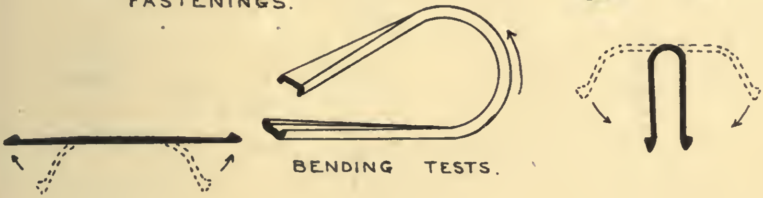
NETHERLANDS STATE RAILWAYS.



DEVELOPMENT OF METAL TIES.

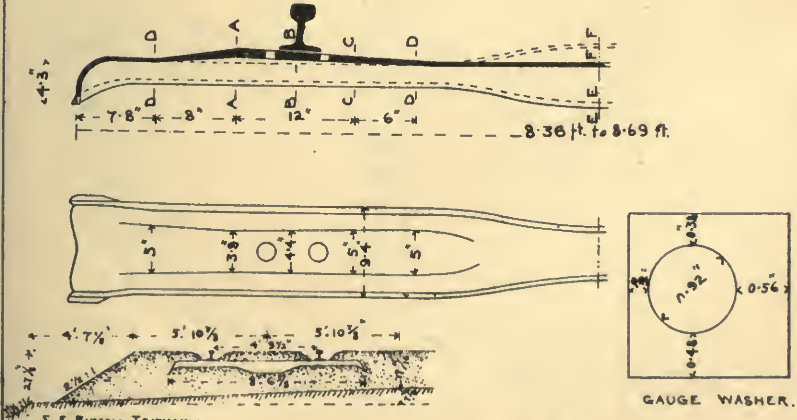


FASTENINGS.



BENDING TESTS.

LATEST TYPE OF "POST" TIE.



GAUGE WASHER.

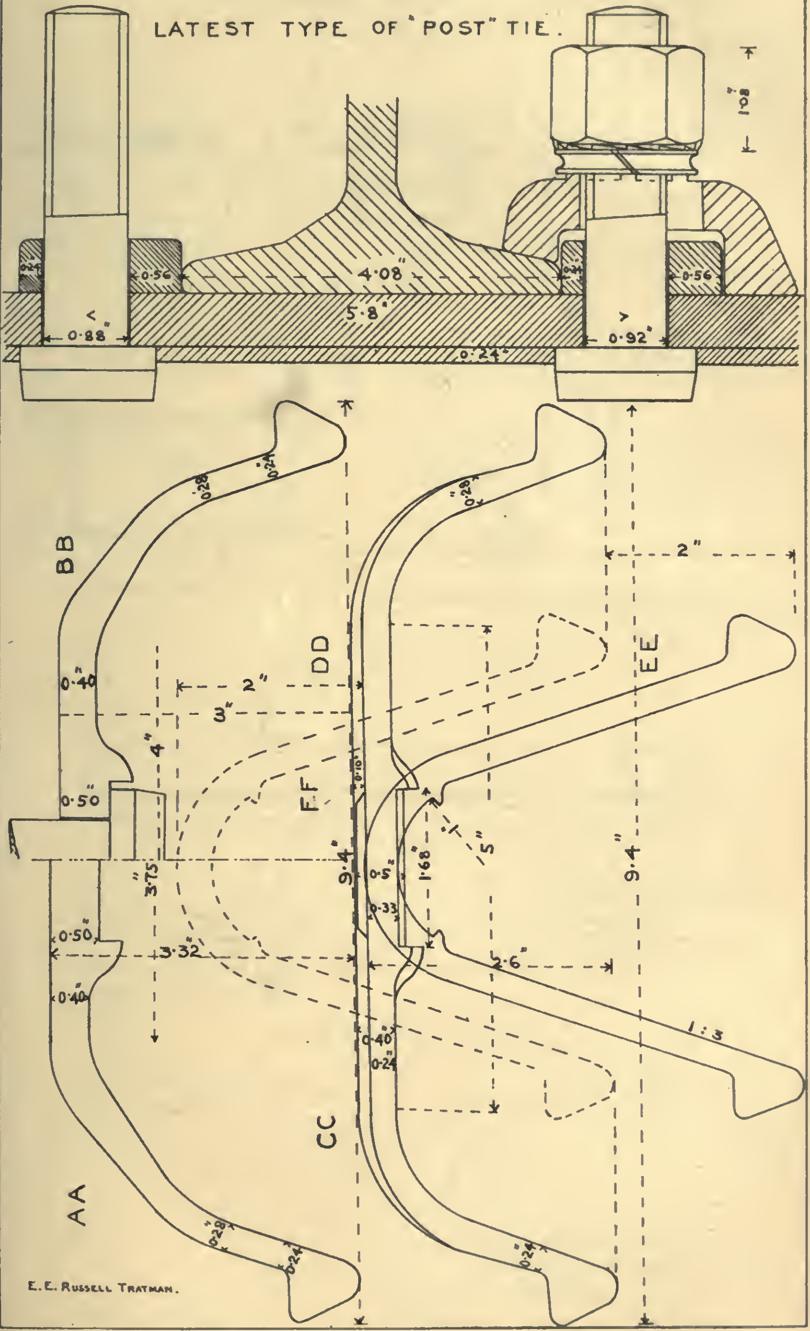
E. E. Russell Tratman.

HOLLAND

PLATE No. 9.

NETHERLANDS STATE RAILWAYS.

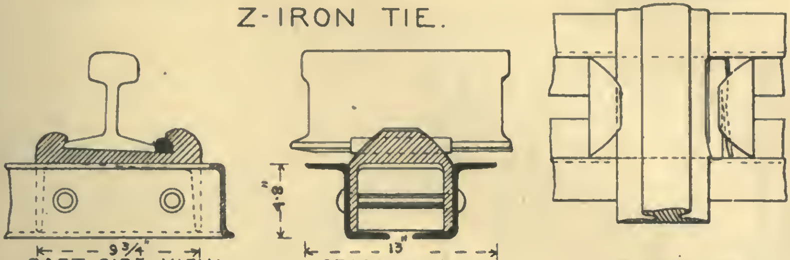
LATEST TYPE OF "POST" TIE.



BELGIUM.

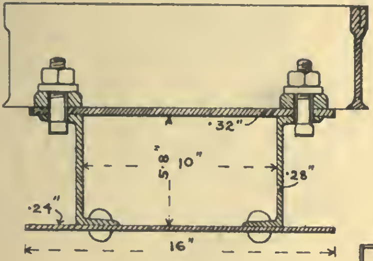
PLATE No. 10.

Z-IRON TIE.

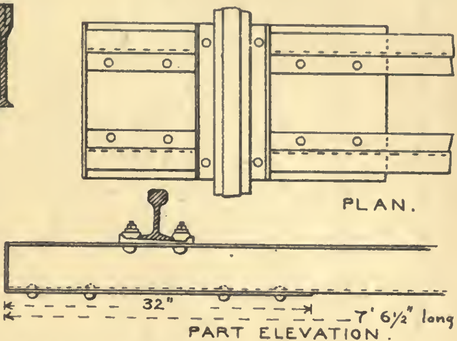


PART SIDE VIEW.   CROSS SECTION.   PLAN.

BERNARD TIE



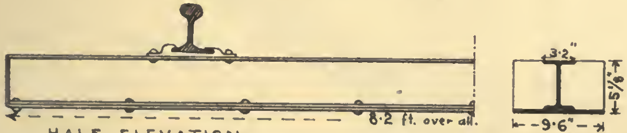
CROSS SECTION.



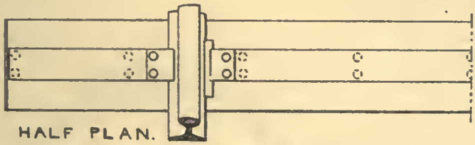
PLAN.

PART ELEVATION.

SEVERAC TIE.



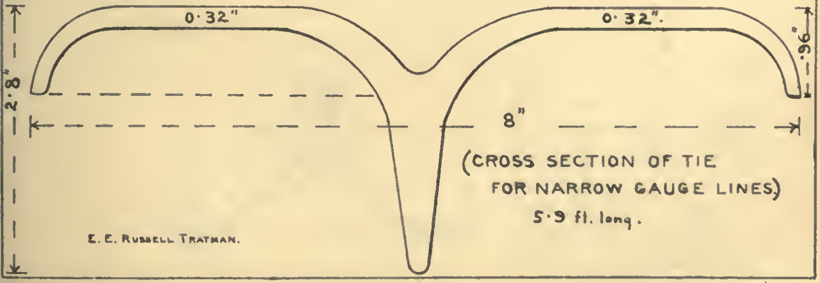
HALF ELEVATION.   CROSS SECTION.



HALF PLAN.

I-Beam,
8·13 ft. long, 3·2 ins. wide,
4·8 ins. high, 0·3 in. thick.
Bottom Plate,
8·2 ft. long, 9·6 ins. wide,
0·32 in. thick.

COBLYN TIE.



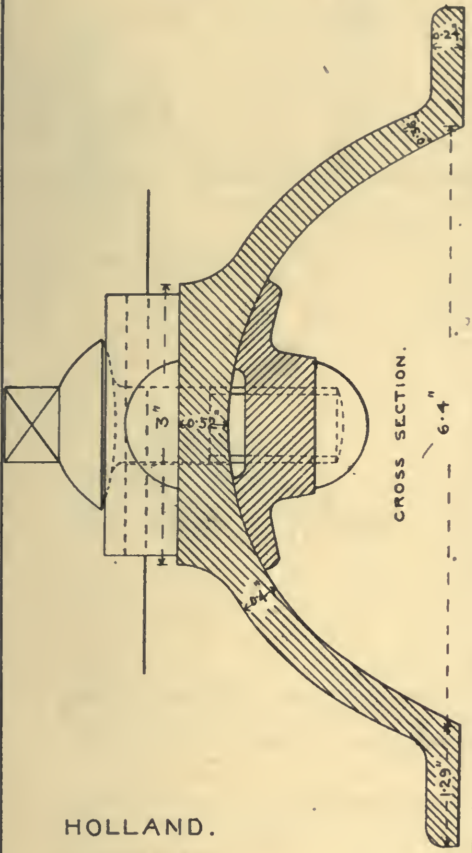
(CROSS SECTION OF TIE
FOR NARROW GAUGE LINES)
5·9 ft. long.

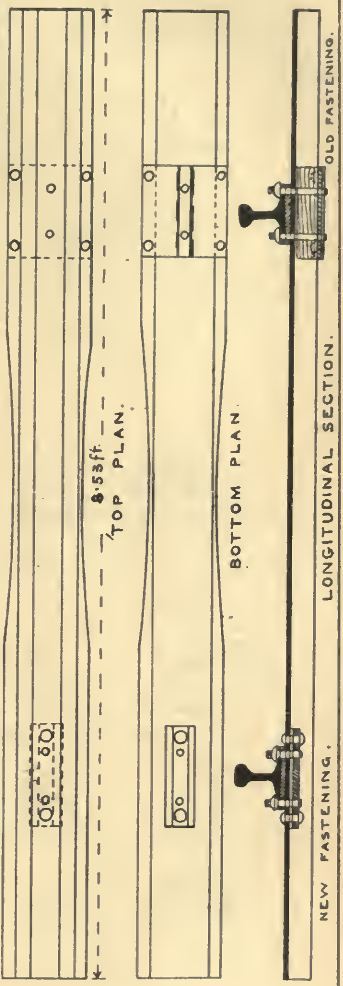
E. E. RUSSELL TRATMAN.

BELGIUM.

PLATE No. 11.

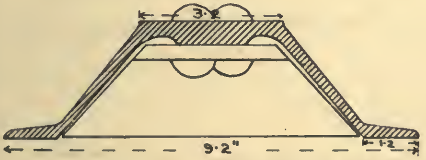
GREAT CENTRAL RY.





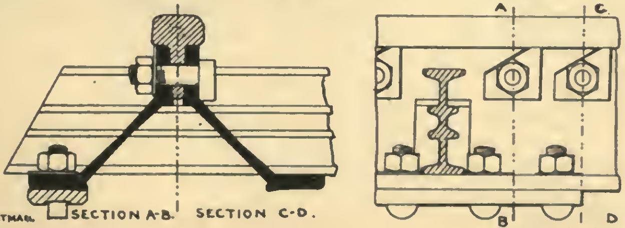
HOLLAND.

DUTCH RYS.



AUSTRIA AND BELGIUM.

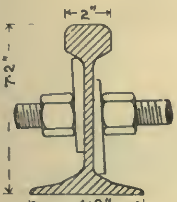
SERRES AND BATTIG SYSTEM.



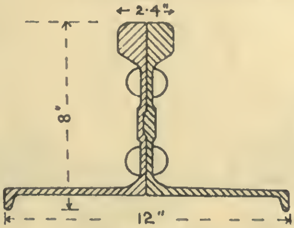
E. E. RUSSELL TRATMAN. SECTION A-B. SECTION C-D.

GERMANY. PLATE No. 12.

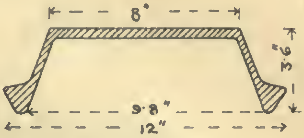
LONGITUDINALS.



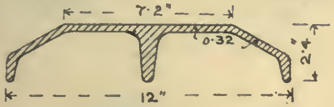
HARTWICH.



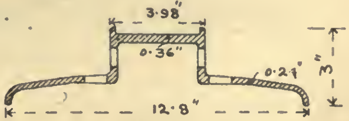
HAARMANN.



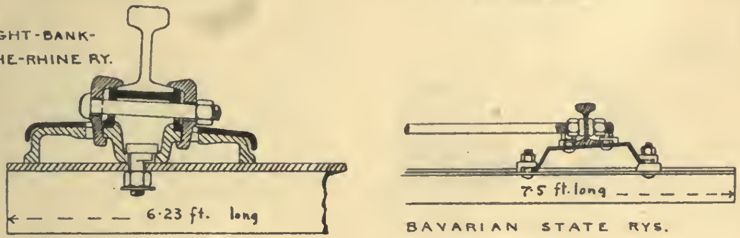
RHENISH.



HILF.



HAARMANN.

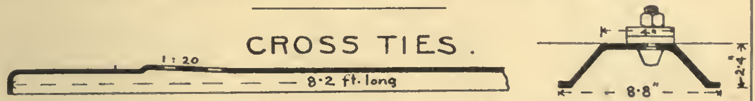


RIGHT-BANK-OF-THE-RHINE RY.

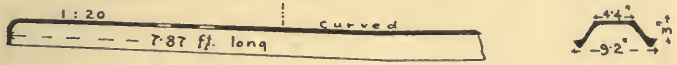
BAVARIAN STATE RYS.

JOINT AND TRANSVERSE TIE.—HAARMAN AND RHENISH TYPES.

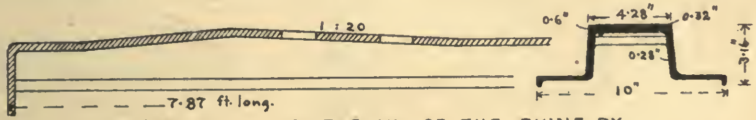
CROSS TIES.



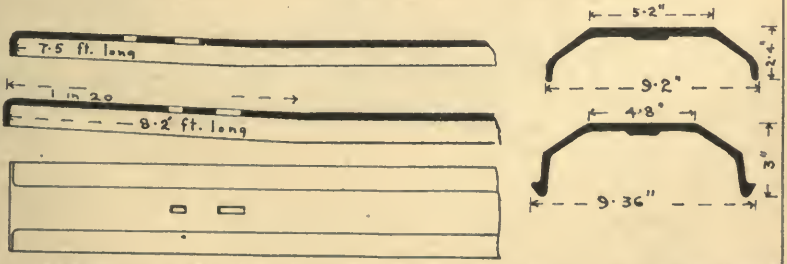
VAUTHERIN (ORIGINAL SECTION). — MAIN - NECKAR RY.



VAUTHERIN (MODIFIED SECTION). — ALSACE-LORRAINE RYS.



HAARMANN. — RIGHT BANK OF THE RHINE RY.



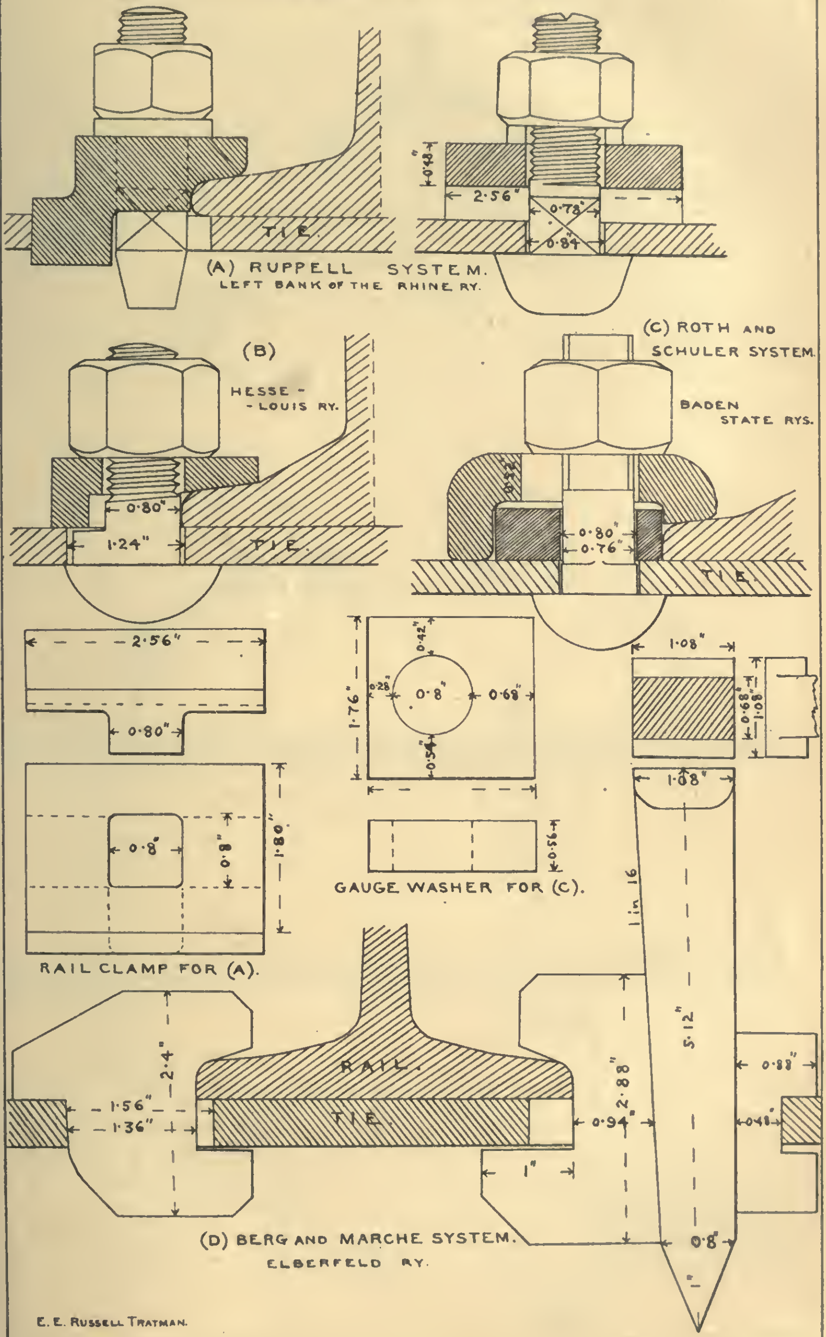
BERG AND MARCHE (ORIGINAL AND MODIFIED SECTIONS).—ELBERFELDR

E. E. Russell Tratman.

GERMANY.

PLATE No. 13.

FASTENINGS.



(A) RUPPELL SYSTEM.
LEFT BANK OF THE RHINE RY.

(B) HESSE-LOUIS RY.

(C) ROTH AND SCHULER SYSTEM.
BADEN STATE RYS.

RAIL CLAMP FOR (A).

GAUGE WASHER FOR (C).

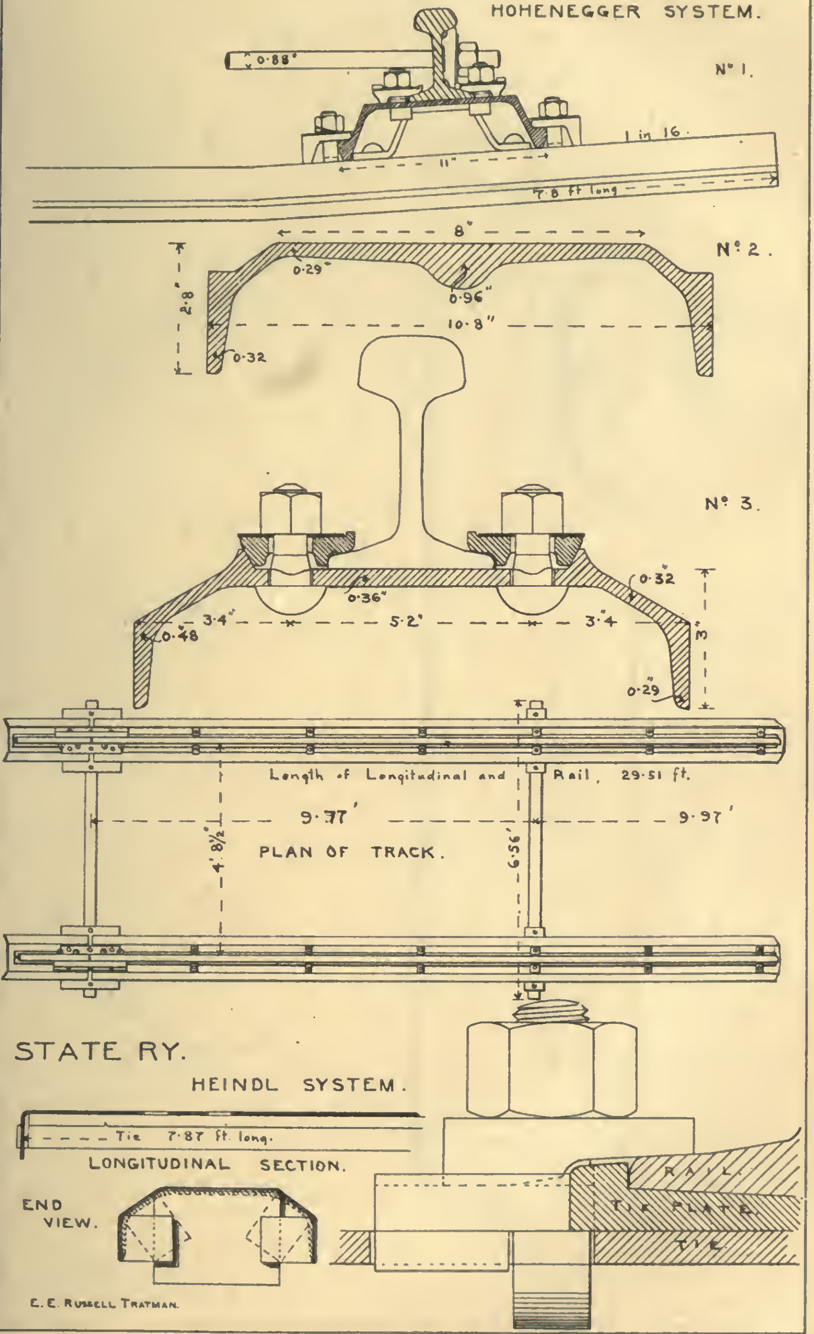
(D) BERG AND MARCHE SYSTEM.
ELBERFELD RY.

E. E. RUSSELL TRATMAN.

AUSTRIA.

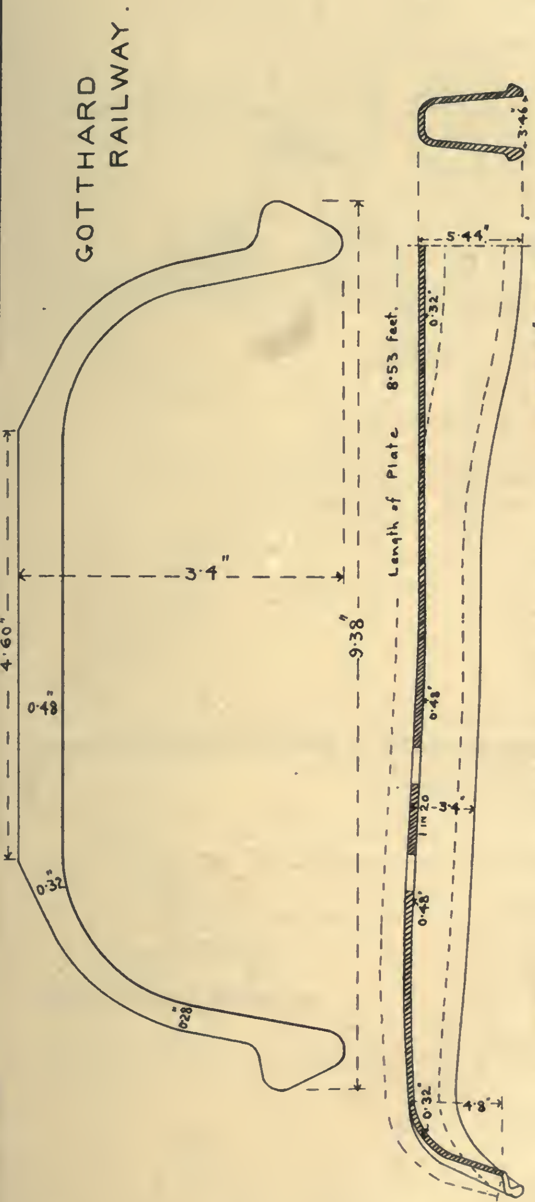
PLATE No. 14.

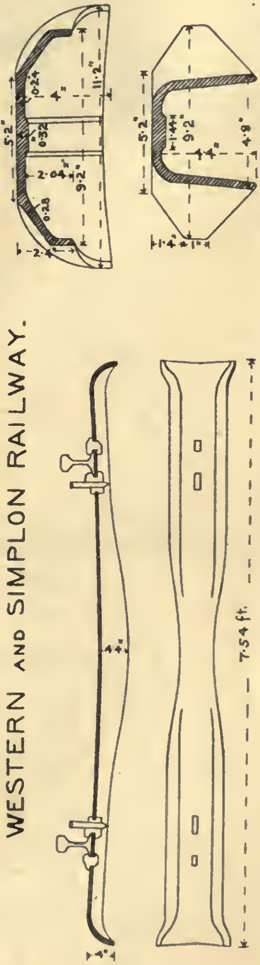
NORTHWESTERN RY.



SWITZERLAND.

PLATE No. 15.



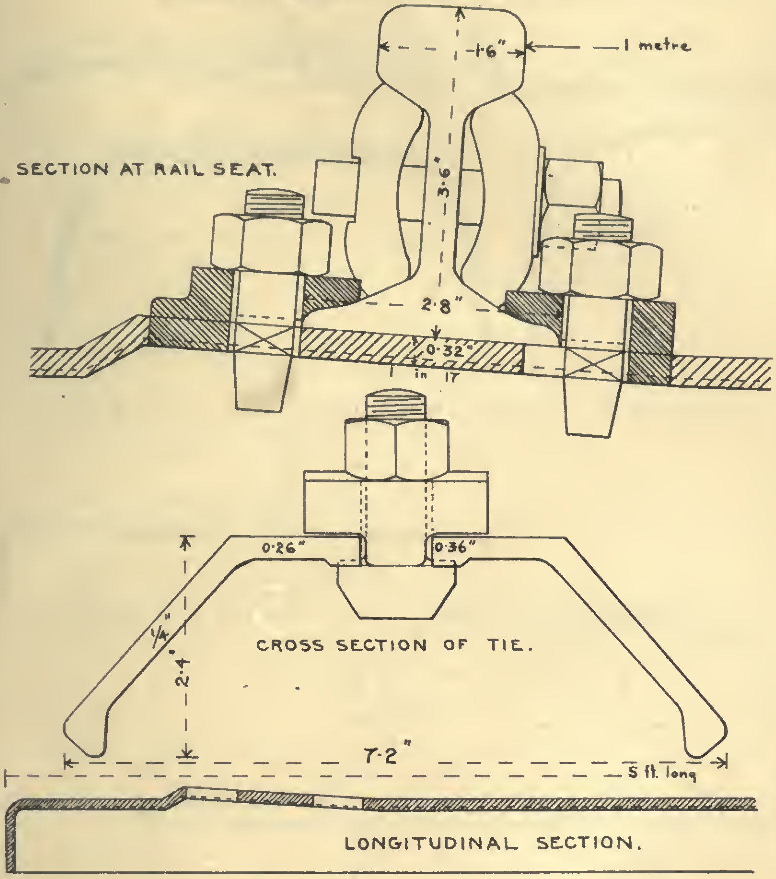


E. E. Russell Tratman.

SPAIN

PLATE No. 16.

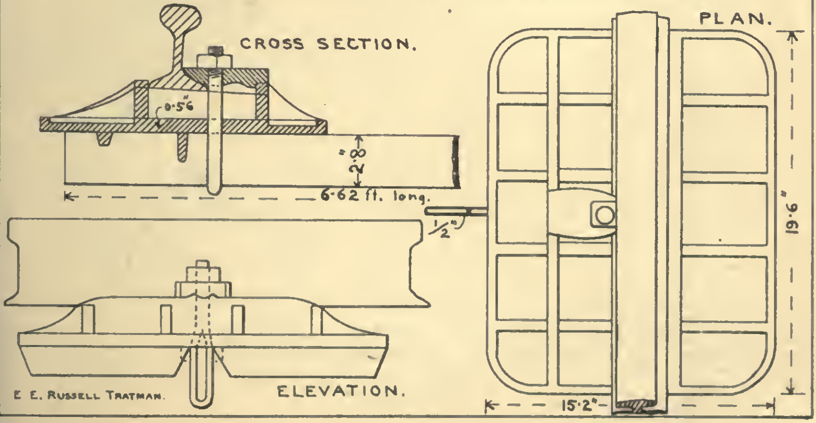
BILBAO & LAS ARENAS RY.


SECTION AT RAIL SEAT.

CROSS SECTION OF TIE.

LONGITUDINAL SECTION.

ALMANSA, VALENCIA & TARRAGONA RY.


CROSS SECTION.

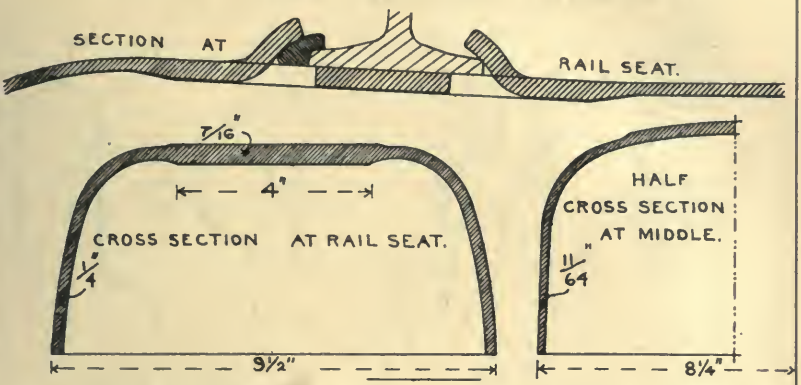
PLAN.

ELEVATION.

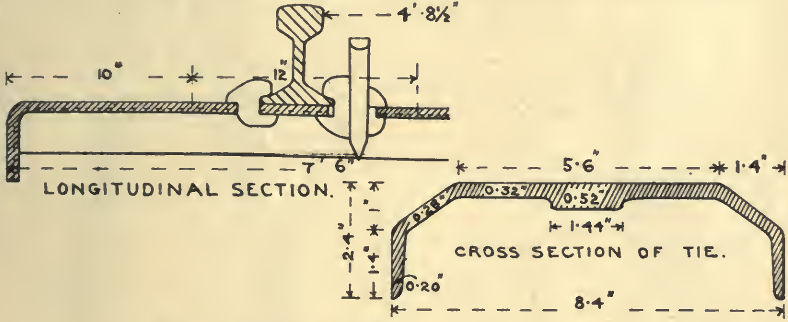
E. E. Russell Tratman.

AFRICA. PLATE No. 17.

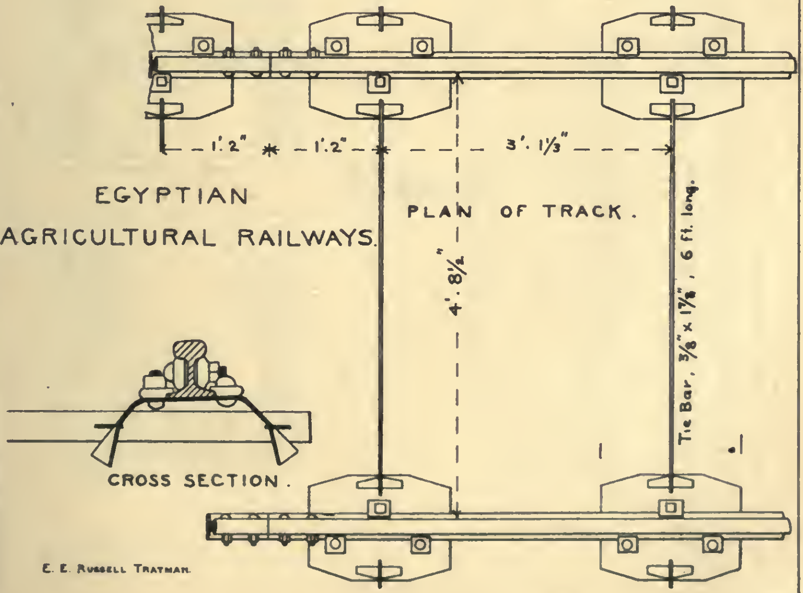
DELAGOA BAY & EAST AFRICAN RY.



P. L. & M. RY. CO. (FRANCE) - ALGERIAN RAILWAYS.



EGYPTIAN AGRICULTURAL RAILWAYS.

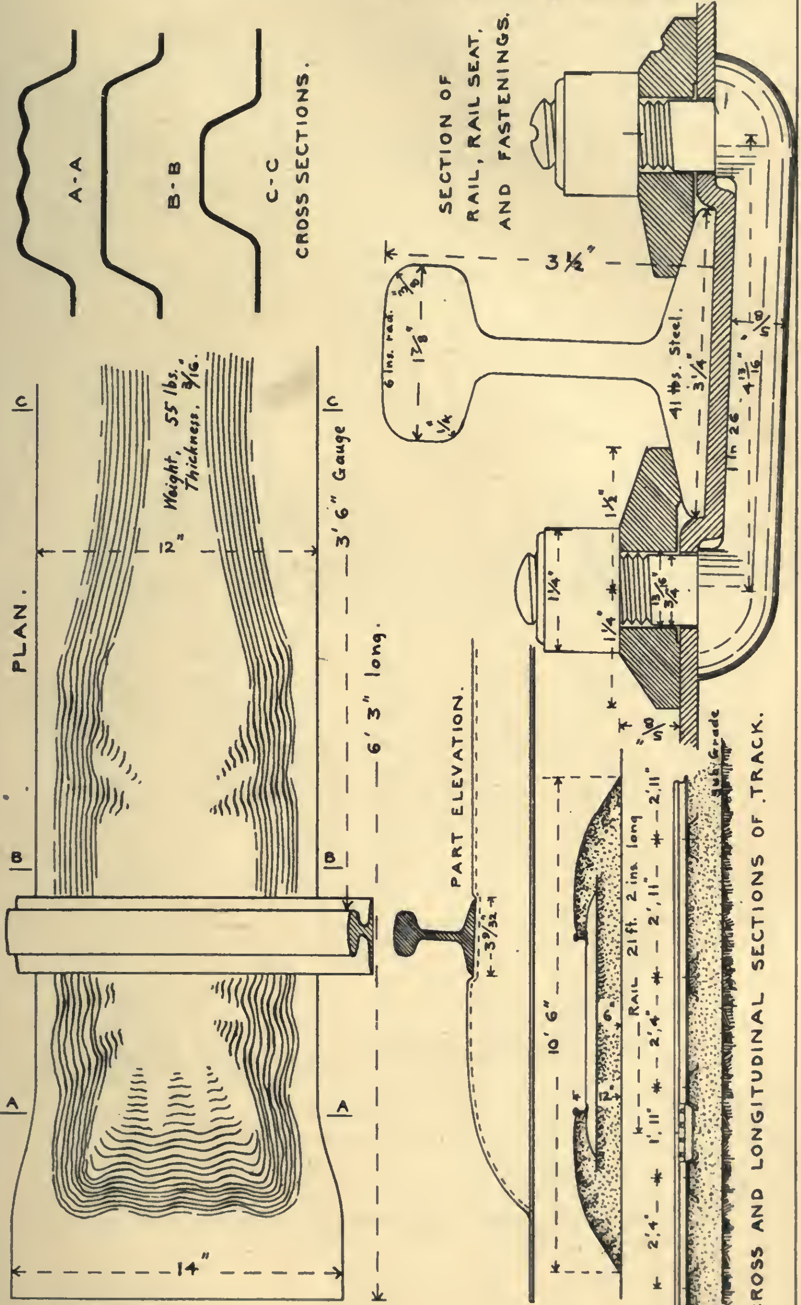


E. E. Russell Tratman.

AUSTRALIA. PLATE No. 18.

SOUTH AUSTRALIAN GOVT. RAILWAYS.

PALMERSTON & PINE CREEK LINE.

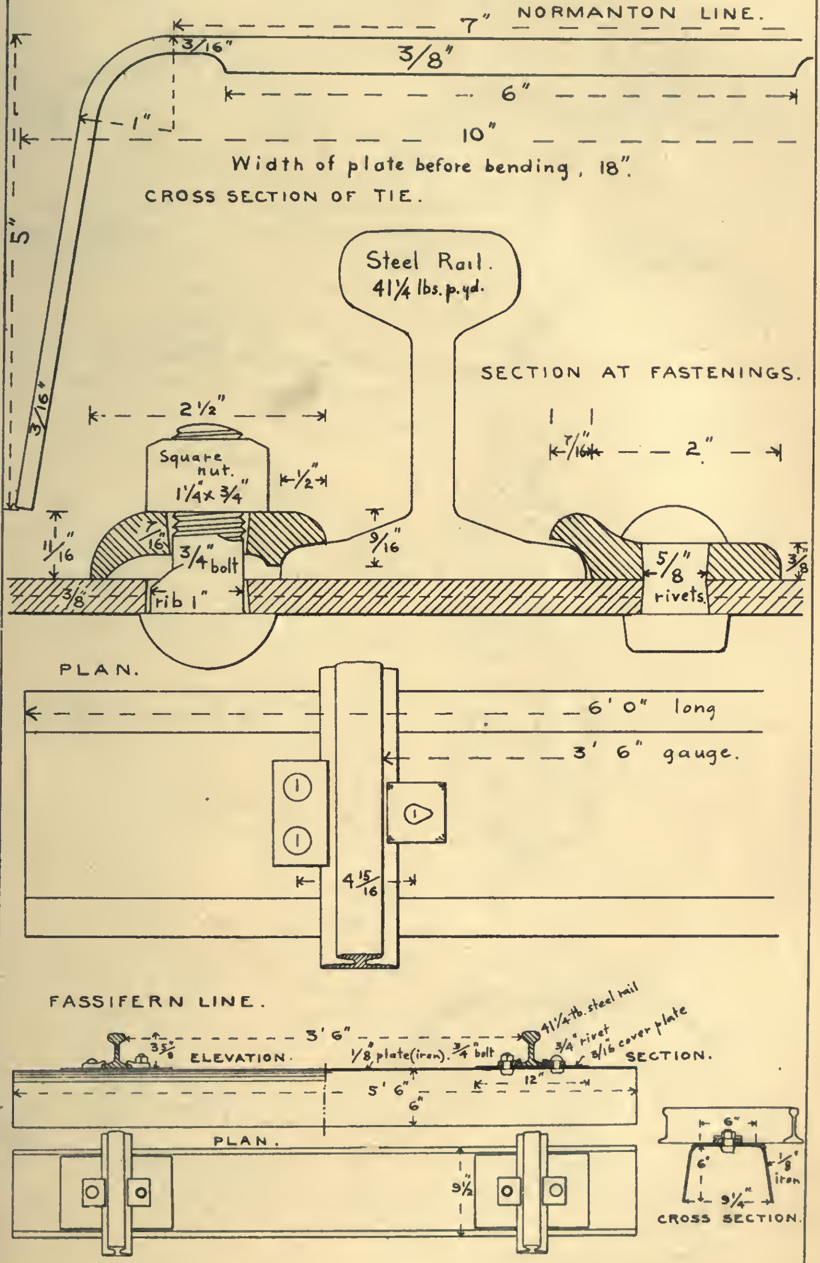


E. E. RUSSELL TRATMAN.

AUSTRALIA.

PLATE No 19.

QUEENSLAND GOVT. RAILWAYS.

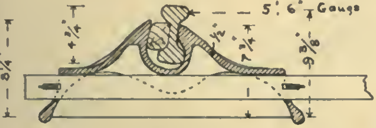


E. E. RUSSELL TRATMAN.

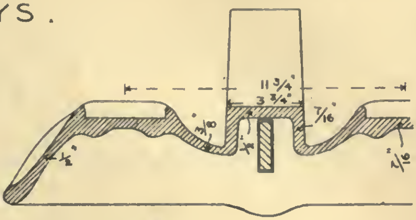
INDIA.

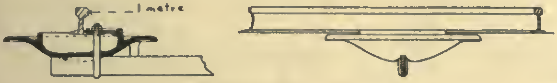
STATE RAILWAYS.

PLATE No. 20.

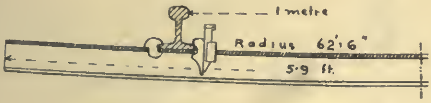


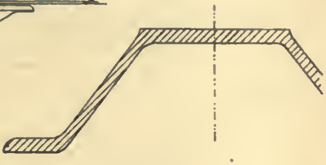
GREAVES' TIE.



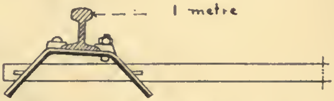


DE BERGUE'S TIE.



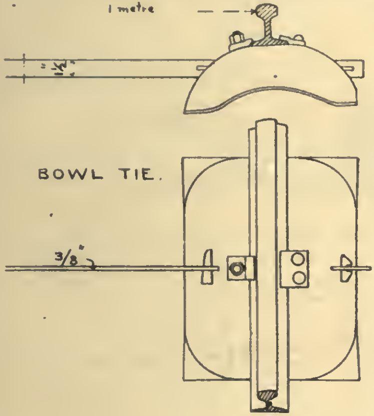


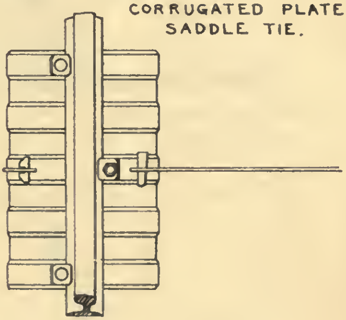
VAUTHERIN'S TIE.



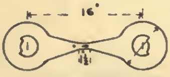
CORRUGATED PLATE SADDLE TIE.

BOWL TIE.

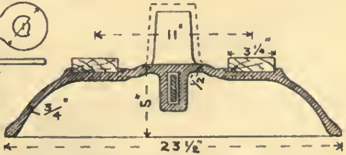




LIVESEY'S TIES.

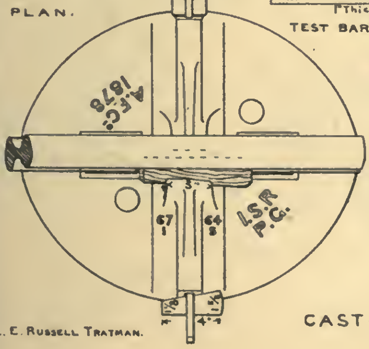


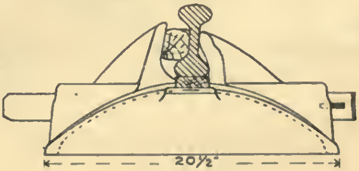
TEST BAR.



LONGITUDINAL SECTION.

PLAN.





END ELEVATION.

CAST-IRON BOWL.

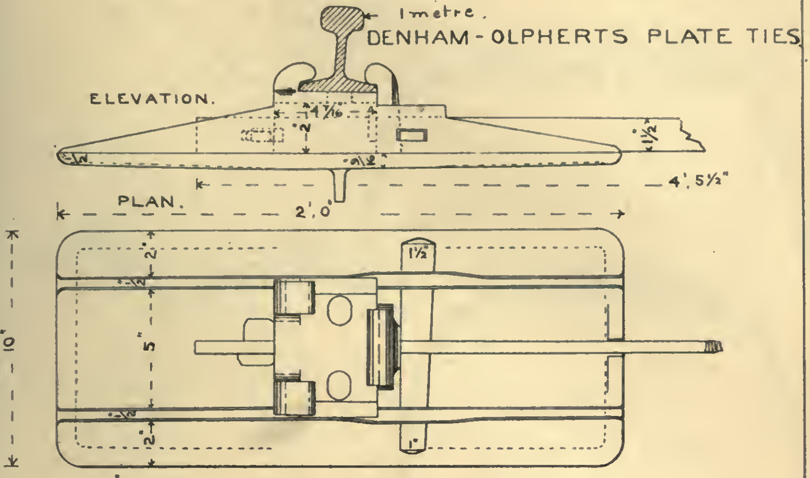
E. E. Russell Tratman.

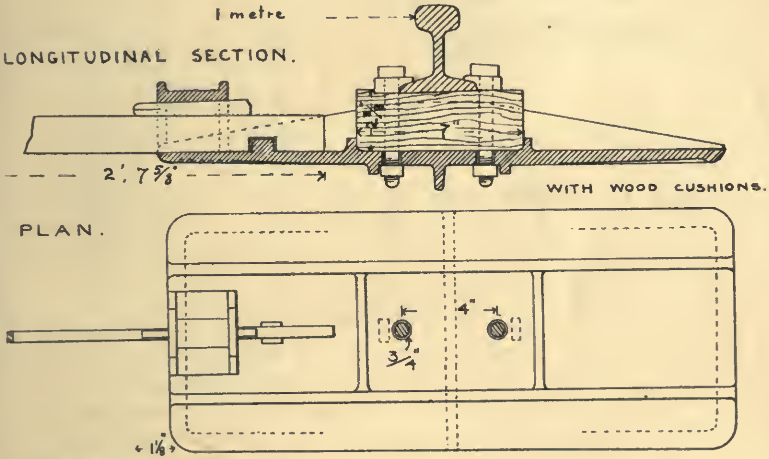
INDIA.

PLATE No. 21.

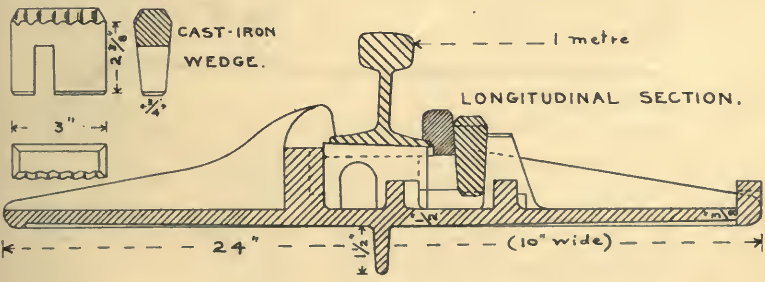
STATE RAILWAYS.

DENHAM-OLPHERTS PLATE TIES.





WITH WOOD CUSHIONS.



D-O PLATE WITH MOLESWORTH'S WEDGE FASTENING.

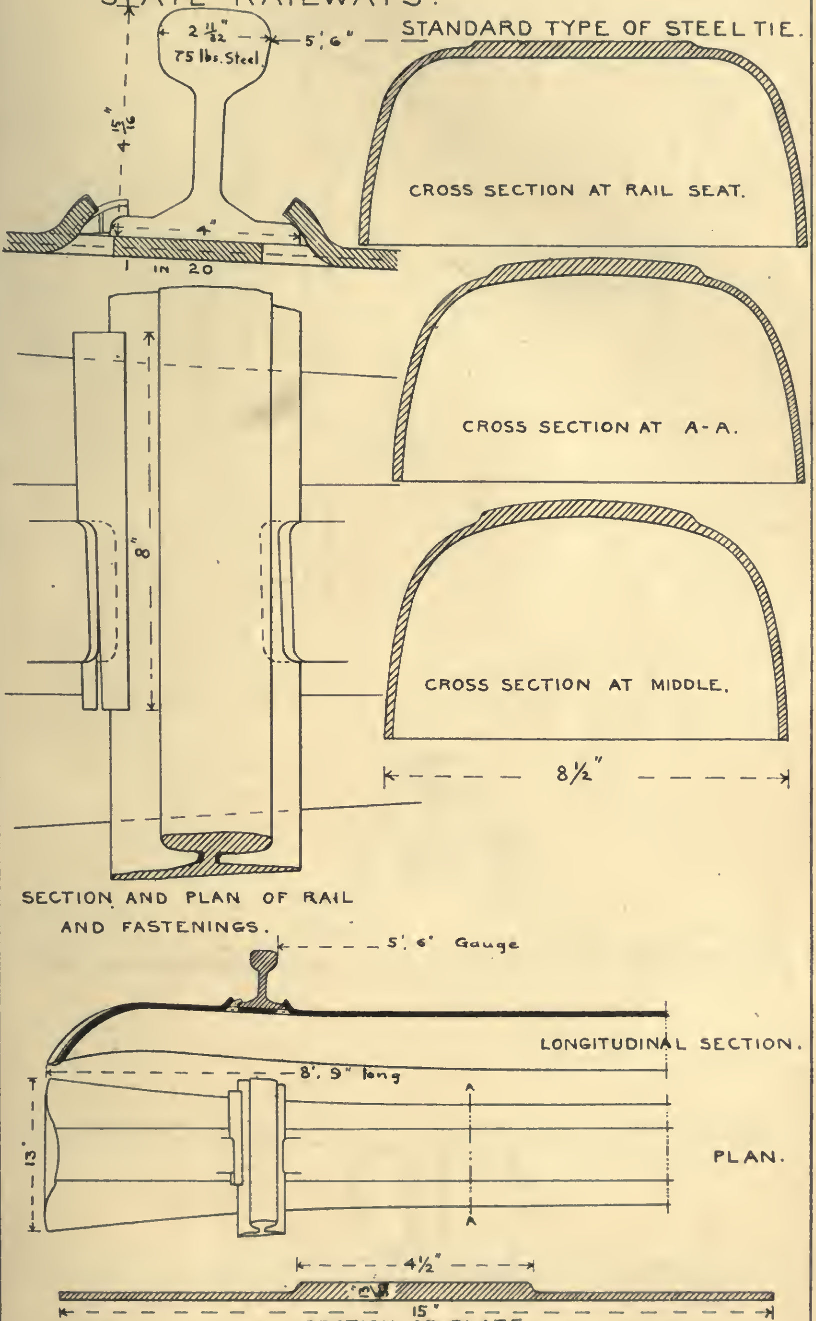
E. E. Russell Tratman.

INDIA.

PLATE No. 22.

STATE RAILWAYS.

STANDARD TYPE OF STEEL TIE.



SECTION AND PLAN OF RAIL AND FASTENINGS.

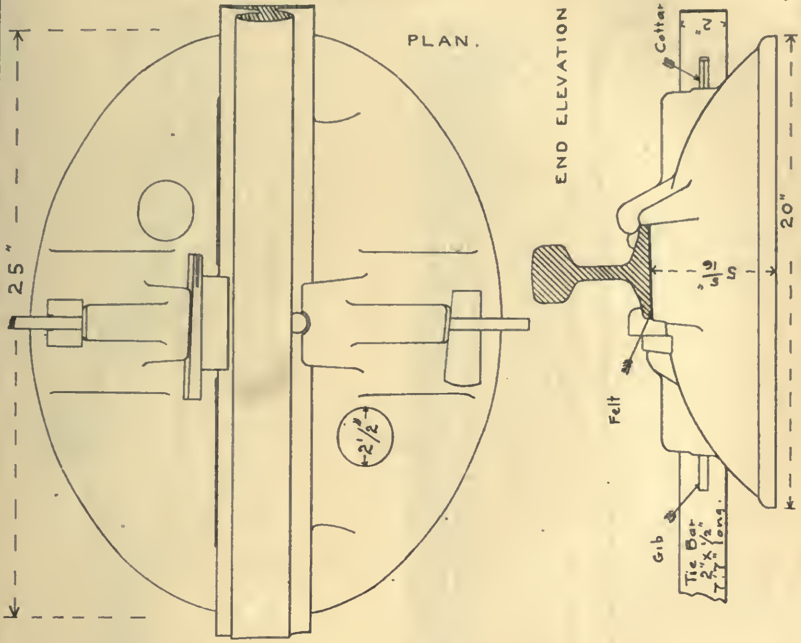
SECTION OF PLATE.

E. E. Russell Tratman.

INDIA.

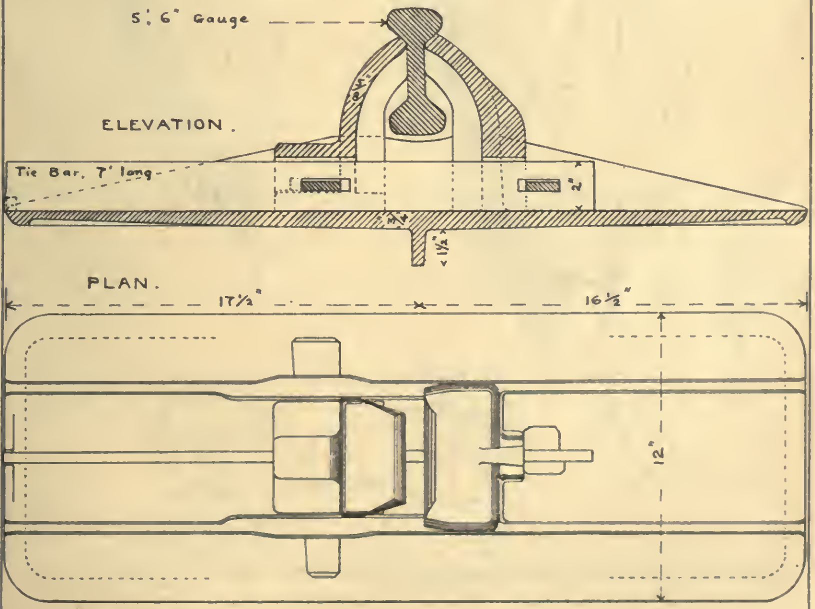
PLATE No. 23.

INDIAN MIDLAND RY.



EAST INDIAN RY.

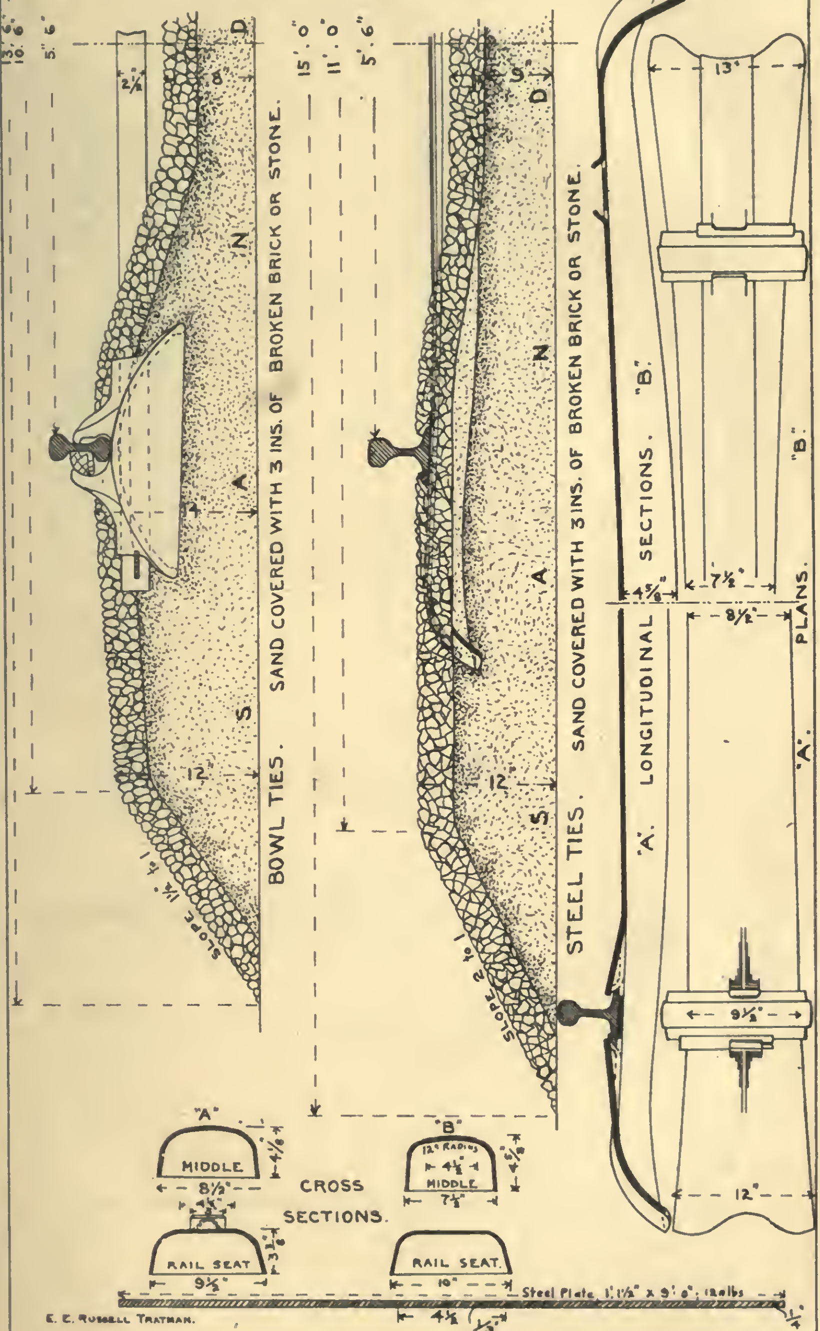
DENHAM-OLPHERTS PLATE TIE.



E. E. RUSSELL TRATMAN.

INDIA. PLATE No. 24.

NORTHWESTERN RY.

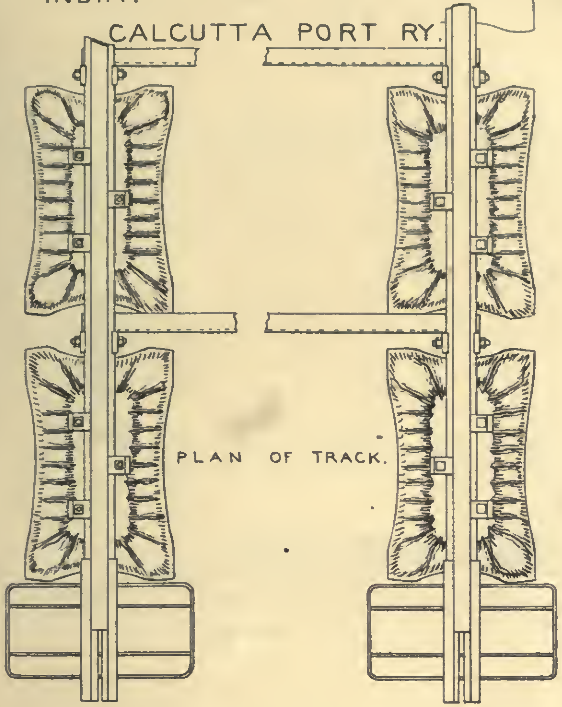


E. E. RUSSELL TRATMAN.

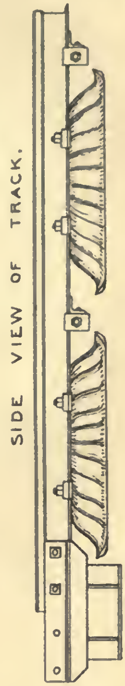
INDIA.

PLATE No. 25.

CALCUTTA PORT RY.

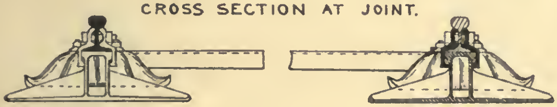


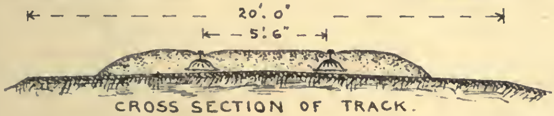
PLAN OF TRACK.



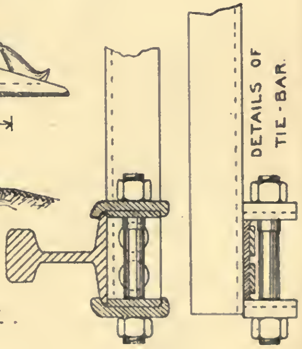
SIDE VIEW OF TRACK.

CROSS SECTION AT JOINT.





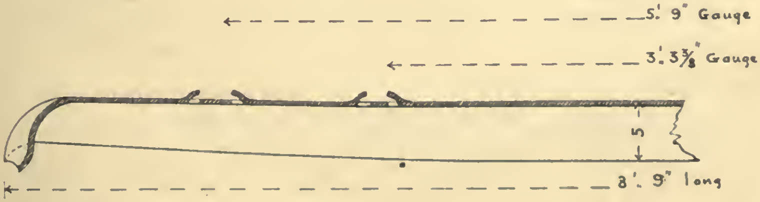
CROSS SECTION OF TRACK.



DETAILS OF TIE-BAR.

BENGAL-NAGPUR RY.

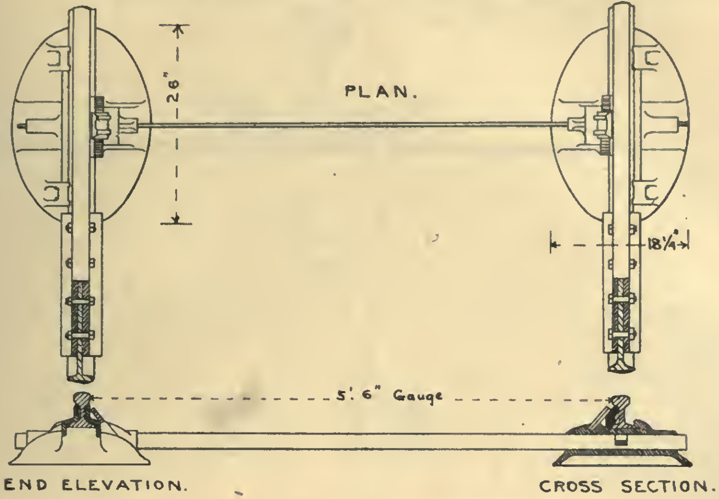
STEEL TIE FOR DOUBLE GAUGE.

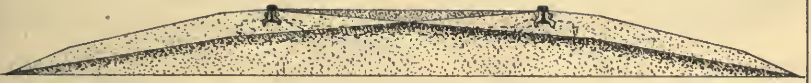


E. E. RUSSELL TRATMAN

ARGENTINE REPUBLIC. PLATE No. 26.

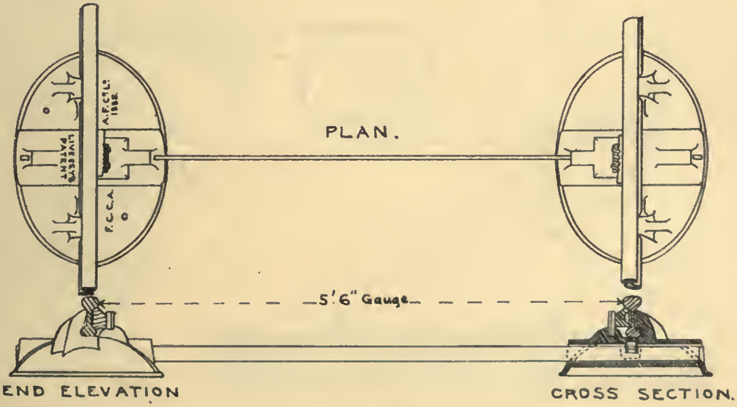
BUENOS AYRES GREAT SOUTHERN RY.

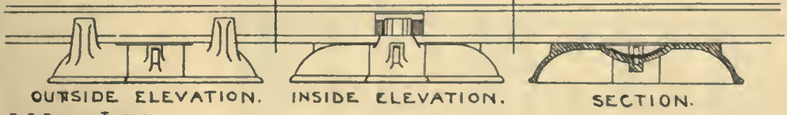




CROSS SECTION OF TRACK.

CENTRAL ARGENTINE RY.





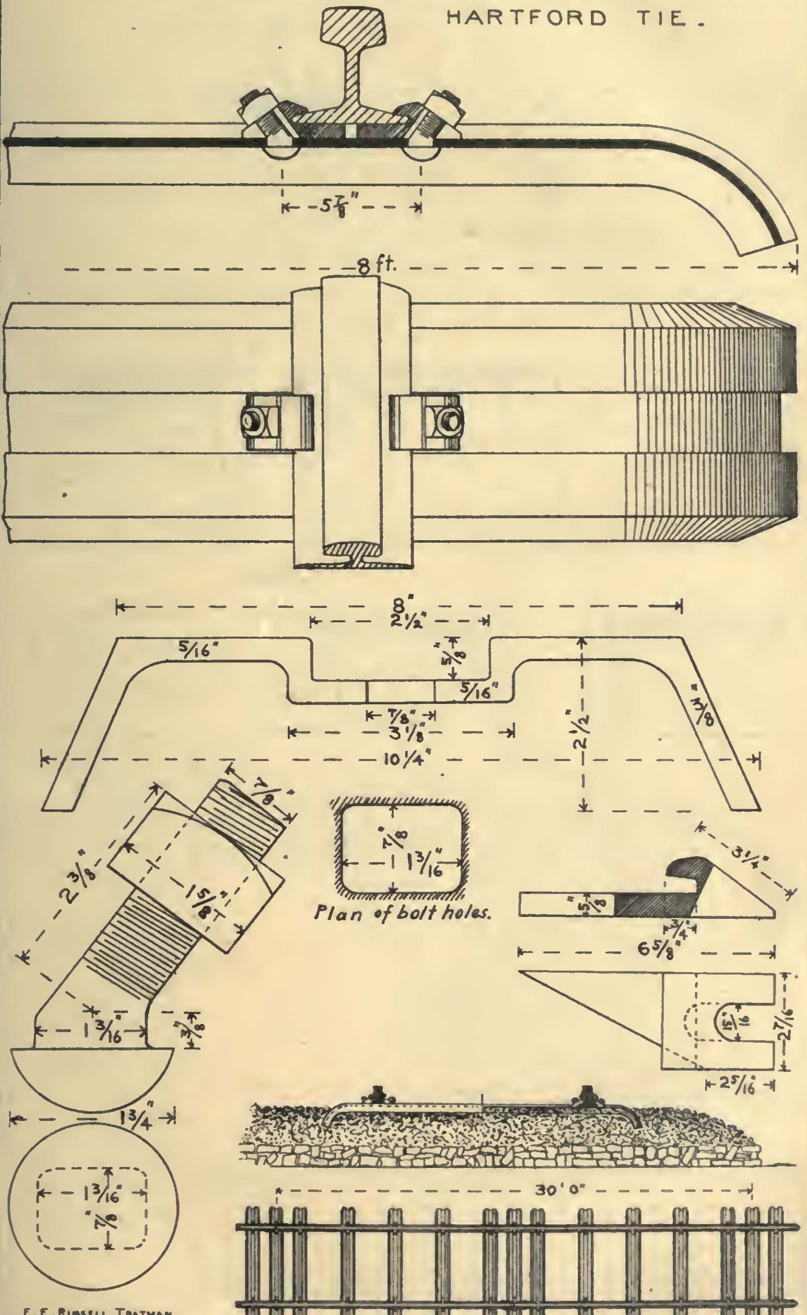
E. E. Russell Tratman.

UNITED STATES

PLATE No. 27.

NEW YORK CENTRAL & HUDSON RIVER RAILWAY.

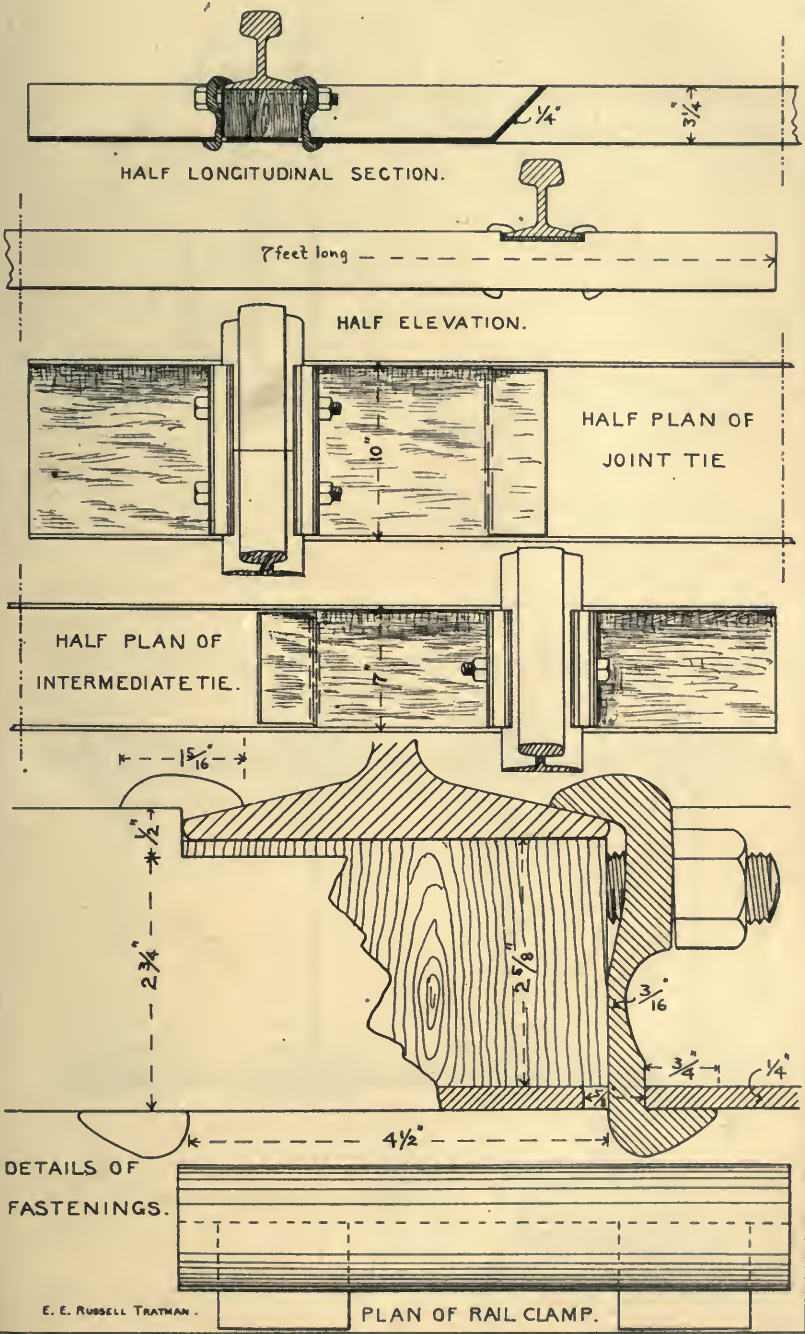
HARTFORD TIE.



E. E. Russell Tratman.

UNITED STATES. PLATE No. 28.

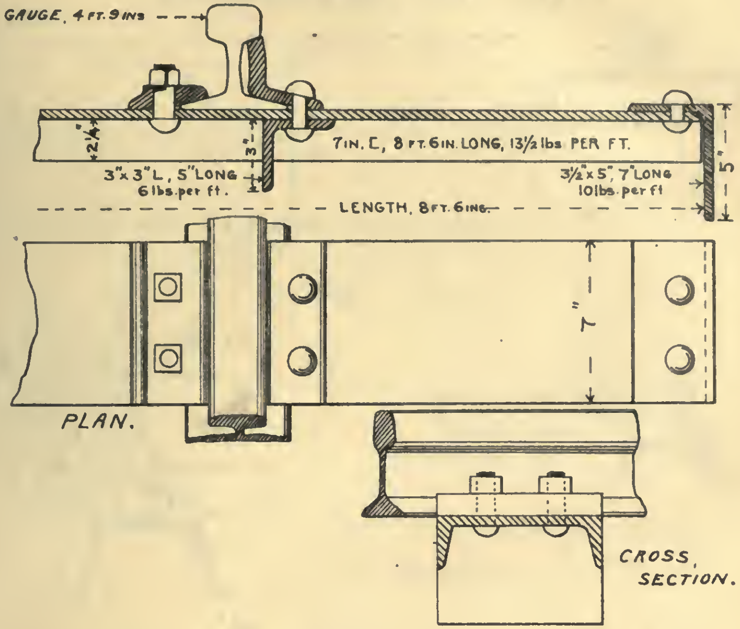
"STANDARD" TIE.



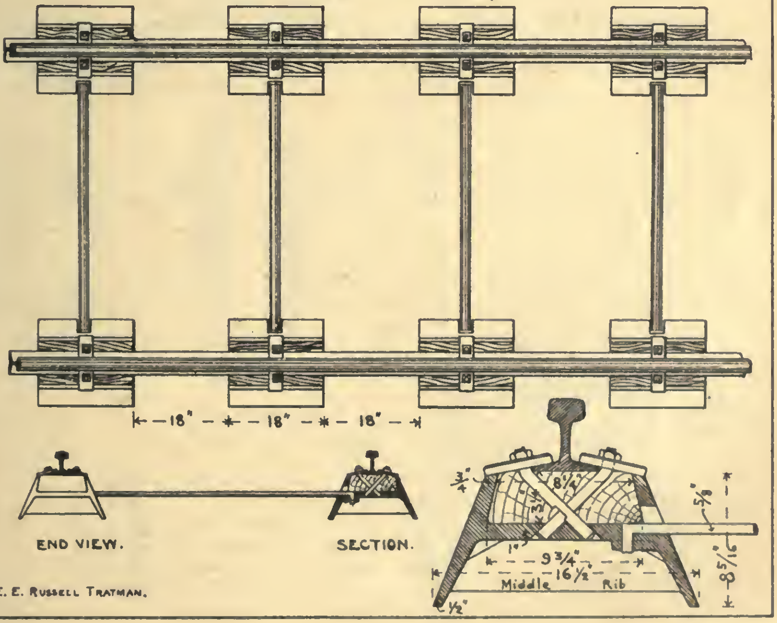
E. E. Russell Tratman.

UNITED STATES. PLATE No. 29.

PENNSYLVANIA RAILWAY.



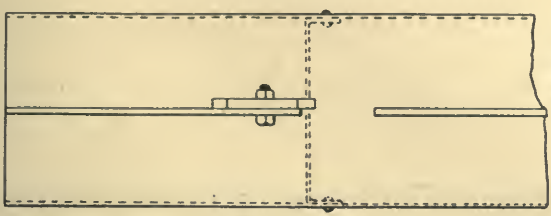
NEW YORK CENTRAL & HUDSON RIVER RAILWAY.
(TOUCEY'S TIE.)



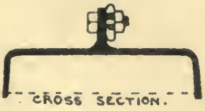
E. E. RUSSELL TRATMAN.

UNITED STATES. PLATE No. 30.

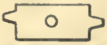
"INTERNATIONAL" TIE.



PLAN.

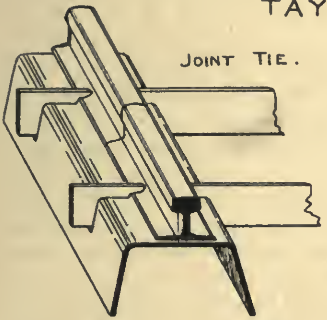


CROSS SECTION.

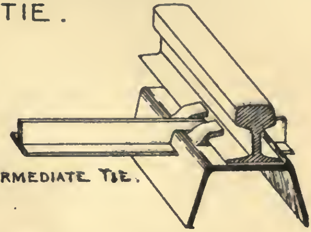


RAIL CLAMP.

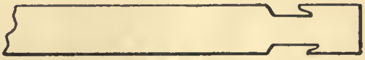
TAYLOR'S TIE.



JOINT TIE.

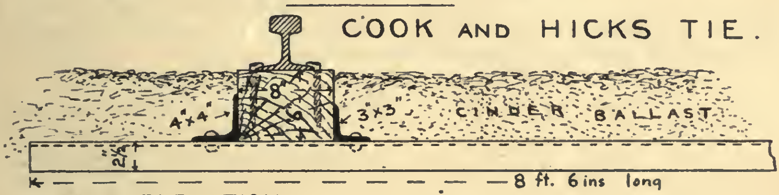


INTERMEDIATE TIE.

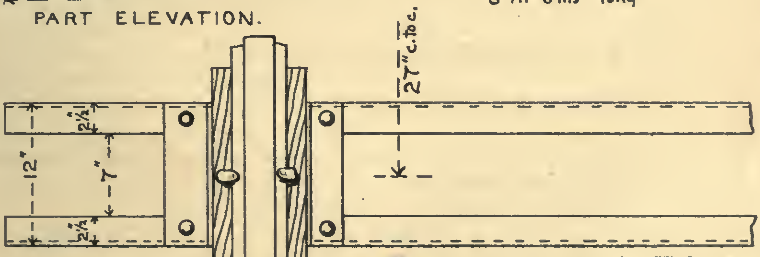


TIE BAR.

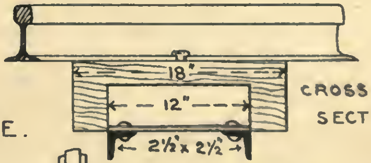
COOK AND HICKS TIE.



PART ELEVATION.

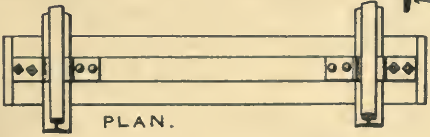


PART PLAN.

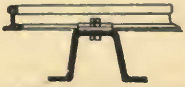


CROSS SECTION

SCOFIELD'S TIE.



PLAN.



CROSS SECTION.

E. E. Russell Tratman.

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FORESTRY DIVISION.
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WHAT IS FORESTRY?

BY

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LETTER OF TRANSMITTAL.

U. S. Department of Agriculture,
Forestry Division,
Washington, D. C., May 20, 1891.

Sir: The unusual interest shown in the subject-matter contained in the following pages, when presented in the form of public addresses delivered by me as your representative before various bodies (notably before the State Boards of Agriculture of Kansas and Nebraska and the Chamber of Commerce of Rochester, New York), makes it appear desirable to publish the same for a larger audience.

At first sight it may be thought incongruous to present under one cover the two aspects of forestry, the reader from the treeless plains being seemingly not interested in the treatment of the forest cover in wooded country, and *vice versa.*

But while on general principles it is desirable that all citizens should understand the forestry problem as it presents itself in the different parts of the country, the knowledge which is gained in the natural forest is an aid in forest-planting, and the principles which underlie forest planting are also to some extent of influence in forest management. Hence both aspects are best presented together.

Since forest planting in the plains is still largely a matter of experiment, I have deemed it desirable to append two contributions from correspondents relating their experience, and the results of actual though limited practice in the field.

B. E. Fernow,
Chief of Forestry Division.

Hon. J. M. Rusk,
Secretary of Agriculture.

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WHAT IS FORESTRY?

I. THE FOREST AND ITS SIGNIFICANCE.

The "forest primeval" is our most valuable inheritance. It is the ready cash of nature's bountiful provision for our future. Of all the natural resources reserved for our use it is the most directly useful, for in the forest we find ready to hand, without further exertion than the mere harvesting, the greatest variety of material applicable to the needs of man, the means to satisfy every direct want of life.

The accumulations of centuries are stored in the tree growth of the virgin forest and in the forest floor of decayed foliage. The giants which we cut down to-day are the result of nature's unaided forces, which in the Sequoias have been at work for over 2,000 years, while rarely less than 200 years' annual growth is represented in any of the trees we now utilize.

Nature has taken no account of time or space, both of which were lavishly at her command; nor did she care whether the forest was composed of the timbers most useful to man; tree growth, whatever the kind, satisfied her laws of development.

But when man begins to occupy the ground, when a growing nation has need of the soil for agricultural use and for timber, when the forest gives way to the field and meadow, it becomes necessary in time to introduce economy into the use of our inheritance, to relegate the forest to the non-agricultural soils, and to make the soil do full duty in producing only that which is useful to man.

When this stage of development has been reached in a nation, when increasing population calls for economical use of resources, when it becomes desirable to reserve the soil to that use under which it is best fitted to satisfy human wants, then a new conception of the forest arises.

The "forest primeval" then, together with the young natural growth of the better class, becomes "woodlands;" the brush lands, which result from the careless treatment of the original growth, become "waste lands," and the name of "forest" is reserved to those woodlands, which have become objects of human care, producing to the fullest capacity of the soil the most useful material.

No more convincing argument for the importance of this resource in a nation's economy can be offered than to state the value of the forest product in the United States.

The total annual product of wood material of all sorts consumed in the United States may be valued in round numbers at $1,000,000,000, representing, roughly speaking, 25,000,000,000 cubic feet of wood, or the annual increase of the wood growth of 500,000,000 acres of forest in fair condition. This value exceeds ten times the value of our gold and silver output, and three times the annual product of all our mineral and coal mines put together. It is three times the value of our wheat crop; and with all the toil and risk which our agricultural crops involve they can barely quadruple the value of this product yielded by nature for the mere harvesting.

If to the value of our total mining product be added the value of stone quarries and petroleum, and this sum be increased by the estimated value of all the steamboats, sailing vessels, canal boats, flatboats, and barges plying in American waters and belonging to citizens of the United States, it will still be less than the value of the forest product by a sum sufficient to purchase at cost of construction all the canals, buy up at par all the stock of the telegraph companies, pay their bonded debts, and construct and equip all the telephone lines. The value of the annual forest product exceeds the gross income of all the railroad and transportation companies. It would suffice to pay the indebtedness of all the States, if we leave out New York and Pennsylvania, including that of all counties, townships, school districts, and cities within those States (in 1880); and it would more than wipe out the remaining public debt of the United States. In fact, ranking manufactures of all kinds and agriculture as respectively first and second in importance, as far as production of values goes, the forest product occupies the third place. This was the case according to the census of 1880. It is claimed that since then the lumber industry has enlarged to such an extent as to make its product second, if not first in value.

The capital employed in merely milling this product, aside from that employed in the harvesting, is roughly estimated at $650,000,000, and there are more than 300,000 people occupied in the direct manufacture of forest and sawmill products alone, not to count the employment afforded by its transportation to centers of consumption and its remanufacture.

It would lead us through all phases and employments of human life were we to attempt an enumeration of the uses to which forest products are put.

Not only does the forest furnish the material for the construction of dwellings and other structures, our railroad consumption of 500,000,000 cubic feet of timber included, but countless articles of domestic economy and implements necessitate its use. Not only does it yield to two-thirds of our population the fuel to warm their houses and to prepare their food, but it gave us the first means of using our mineral resources, and even now 600,000 tons of the iron product depend upon charcoal. Not only does the wood in its natural form serve our needs, but our ingenuity has invented methods by which we can transform it into all sorts of useful materials, like cellulose, paper, and even silk, while lately it has become possible to prepare from the brushwood a feed for cattle more nutritious than straw and equal to hay.

By distillation of the wood numerous new products are derived from it, like alcohol, acetic acid, gas, vanillin, etc., and if we recall that the bark yields indispensable tanning material, that resin and tar to pitch our vessels, and turpentine, sassafras oil, and quinine to cure our ills, rubber and cork for a great variety of uses, maple sugar and cinnamon to flavor our food, all are derived from the forest, it will be admitted that an enumeration of the use of forest products would be almost endless. And in spite of the discovery of substitutes for many uses the application of wood is growing everywhere in direction as well as in quantity.

While this direct usefulness of the forest is patent to everyone, there are to be noted some more hidden indirect phases of utility as important as those which are presented by its material.

The forest, with its decaying vegetation, has furnished the fertility of our fields and waters, for the mineral soil without the humus or vegetable mold would never have produced food enough for mankind.

Another incalculable benefit of the forest cover has impressed itself upon the minds of the observing and thinking portion of mankind only comparatively recently, namely, the part which the forest plays in the great economy of nature, the recognition of which led the most eminent naturalist and philosopher, A. von Humboldt, to exclaim: "How foolish do men appear, destroying the forest cover without regard to consequences, for thereby they rob themselves of wood and water."

It is only within a century or so that the value of a forest cover as a protection against destructive natural forces and as a regulator of favorable cultural conditions, by its influence upon climatic conditions, and upon the flow of water, has been recognized and proved.

Whatever may in general remain unexplained or unproved in regard to these influences of the forest, it is well established by observation, experience, and experiment that under certain conditions of soil, topography, and climate these influences not only exist, but are of considerable importance in preventing the washing and shifting of the soil, regulating the surface and subterranean drainage of waters, breaking the force of and tempering hot and cold winds, and thus acting as a regulator of cultural conditions.

We see, then, that the significance of the forest is twofold. For the private interest it is, in the first place, only a source of profitable products; the more profit it affords the more fully does it satisfy this interest.

For the interest of the community, the State, or Nation, it forms an indispensable basis of material prosperity, directly and indirectly. The more fully, and especially the more continuously, this function is fulfilled, the more fully is the interest of the community subserved.

Forest management, therefore, a proper maintenance of forest cover where desirable, supplies not only profitable employment for private enterprise, but is also an important factor of public economy, and the application of proper forestry principles is hence a matter of public interest.

II. FORESTRY IN A WOODED COUNTRY,

OR

FOREST MANAGEMENT.

If left to itself, without interference of man, nature would keep the entire earth, with few excepted localities, under forest cover. It is only when man interferes that this tendency of nature is either frustrated or turned to advantage for the objects of man. If the latter, then we may speak of forest management, and we understand by "management" the bestowal of care, giving direction and applying economy in the use of natural resources.

OBJECTS OF FOREST MANAGEMENT.

Forest management has two objects in view:

1. To produce and reproduce certain useful material.
2. To sustain or possibly improve certain advantageous natural conditions.

In the first case we treat the forest as a crop, which we harvest from the soil, taking care to devote the land to repeated reproduction of crops. As agriculture is practiced for the purpose of producing food crops, so forestry is in the first place concerned in the production of wood crops, both attempting to create values from the soil.

In the second case we add to the first conception of the forest as a crop another, namely, that of a cover to the soil, which under certain conditions and in certain locations bears a very important relation to other conditions of life.

The favorable influence which the forest growth exerts in preventing the washing of the soil and in retarding the torrential flow of water, and also in checking the winds and thereby reducing rapid evaporation, further in facilitating subterranean drainage and influencing climatic conditions, on account of which it is desirable to preserve certain parts of the natural forest growth and extend it elsewhere—this favorable influence is due to the dense cover of foliage mainly, and to the mechanical obstruction which the trunks and the litter of the forest floor offer.

Any kind of tree growth would answer this purpose, and all the forest management necessary would be to simply abstain from interference and leave the ground to nature's kindly action.

This was about the idea of the first advocates of forest protection in this country: Keep out fire, keep out cattle, keep out the ax of man, and nothing more is needed to keep our mountains under forest cover forever.

But would it be rational and would it be necessary to withdraw a large territory from human use in order to secure this beneficial influence? It would be, indeed, in many localities, if the advantages of keeping it under forest could not be secured simultaneously with the employment of the soil for useful production, but rational forest management secures both the advantages of favorable forest conditions and the reproduction of useful material. Not only is the rational cutting of the forest not antagonistic to favorable forest conditions, but in skillful hands the latter can be improved by the judicious use of the ax.

In fact the demands of forest preservation on the mountains and the methods of forest management for profit in such localities are more or less harmonious; thus the absolute clearing of the forest on steep hillsides, which is apt to lead to desiccation and washing of the soil, is equally detrimental to a profitable forest management, necessitating, as it does, replanting under difficulties.

Forest preservation, then, does not, as seems to be imagined by many, exclude proper forest utilization, but on the contrary these may well go hand in hand, preserving forest conditions while securing valuable material; the first requirement only modifies the manner, in which the second is satisfied.

WHERE SHOULD FOREST GROWTH BE MAINTAINED?

The forest is the most unsatisfactory form of vegetation as regards the maintenance of ruminants, and hence of a large population.

Forest destruction is, therefore, the beginning of all culture and its essential prerequisite.

When, however, the land that is fit for purposes of agriculture and grazing has been secured, it will be found that the most successful cultivation of the soil can be carried on when forest areas are interspersed.

If properly located, the wood lot on the farm is a most profitable property, directly and indirectly.

First of all, the waste places, the thin soils that produce little, the rocky and the wet places should be left to tree growth; because not only does the farm look better with the ugly spots covered, but tree growth is the most profitable crop on them. Trees will grow, thrive, and pay good returns without much work. Not that the forest grows best on such sites, but it can grow where no other crop is possible.

Next, there should be left a wood growth on all hillsides too steep to plow comfortably; on all knolls, and, in patches and belts, along all slopes that are subject to washing and gullying, and also a strip along all water courses.

The reason for this is obvious. Wherever one travels in the United States he will, half the year, find our rivers and streams muddy and chocolate-colored, laden with sand and soil. What occasions this condition? The loss of the best part of your farms; millions of dollars' worth of farm values go down the rivers every year for lack of attention to a proper maintenance of forest growth.

The soil is washed by the rains from the fields into brooks and rivers because you have plowed to the water's edge, instead of leaving a belt of forest cover along the banks; it is washed from the slopes and knolls because you have bared them, and the rain beating down first hardens the ground and then being unable to drain off subterraneously has carried the soil and débris down the slope, gullying the hillside, reducing its farm value, and filling up the rivers, while making river and harbor improvements more expensive, and in these you pay the penalty for not keeping your soil at home. It is computed that in the hill lands of the State of Mississippi alone the loss of agricultural lands from this cause amounts to 10 per cent yearly.

The forest cover with its interposing foliage and undergrowth, its protecting floor of fallen leaves and twigs, its intricate root system and its fallen trunks and branches, first retards the rain on its way to the ground, thus breaking its force, and then retards the surface drainage and prevents the rush of water which takes place over naked soil.

And if larger areas are being denuded in a hill country or in the mountains, the chances are that both the flow of springs and the flow of brooks and rivers are made uncertain, because the forest which acts as an equalizer in time and quantity of water-flow is cut off.

The streams that used to keep the ponds well filled for the sawmill and the gristmill and furnished a never-failing supply for the farms, how many of them run dry in summer? And yet with the warm rains of spring and melting snow, they overflow their banks and swift waters carry away fences, bridges, and embankments, and in the larger streams the floods make sad havoc and destroy millions of property.

Thus what the farmer is doing on his farm or leaves undone in the way of forest management is felt not only by himself, but by a large area far away from him, and ultimately the large cities, which depend for power, drinking water, or for navigation upon the regular drainage waters of the country, find themselves in danger and distress.

At first sight to the farmer, who sees only his immediate surroundings, it would appear impossible that his action or inaction should breed such results, but as all great effects are the result of many small causes, so the many little rills and runs and rivulets carrying each its quota of water, earth, and rocks from the denuded slope to the river, make the great floods more dangerous than they were before, because large masses of water run off at once and the débris stows back its flow.

There is another influence of the well-placed wood lot, the absence of which is felt by the farmers in western New York and elsewhere. It is the shelter which the wood lot offered. Now, with the country unduly opened, spring opens later. The young cattle that used to be turned out into the wood-sheltered pasture about the 1st of April now are kept shut up until the middle of May. Peach orchards in Michigan have become impossible in many sections, and those that were sure to be loaded every year with luscious fruit now furnish a good crop only as an exception, and so it is with apples. Droughts in summer and floods in spring time are more frequent and more destructive because the tempering shelter belt and the forest floor are destroyed.

There are also in all parts of the country large mountain areas which with their declivities and thin soils offer little or no inducement to agricultural use and are best kept under forest altogether, partly because that is the most profitable use of the soil, partly because a forest cover is here of most benefit in regulating water conditions, and for this reason the method of managing here must be such that regard to these conditions forms the first consideration in the use of the forest, production of material and values only the second.

Forestry here carried on with the care which such conditions demand may not prove profitable to the private owner, and therefore such forests should be owned, controlled, and managed by the community or the State as an object of public concern, like roads, canals, harbors, and similar public improvements; the interest of the community being here more concerned than the pocket of the individual.

WHAT FOREST MANAGEMENT IS AND WHAT IT IS NOT.

The popularly expressed idea that forest management consists in cutting the mature trees is about as childlike a conception as if we were to define banking business to consist in paying out money. The lumberman hardly does anything but take the mature trees, and yet he thereby in many cases injures the forest, killing out the desirable species and handing the ground over to less desirable growth, because he does not know how to cut so as to reproduce or favor the desirable growth. Thus the cutting of the spruce in the Adirondacks, done in the manner in which it is now practiced, is a practice to be utterly condemned from the forester's point of view, because it reduces the chances for reproduction of the most desirable species.

Nor does forestry consist in planting trees, after the original growth is removed, although that may under certain circumstances form a part of the forester's task.

Least of all does forestry require the prevention of timber-cutting anywhere and everywhere, for that would be to prevent its very object, which, as we have seen, is to grow a crop, to secure, besides favorable forest conditions, desirable material for utilization.

What is the material which a rational forest management tries to secure? Not trees merely—which, to be sure, would satisfy the requirement of maintaining forest conditions, and which nature produces without assistance—nor is it wood simply that is sought by the forest manager; that, too, is produced by nature without his interference, but it is useful wood—wood of qualities that make it applicable to his needs, and, further than that, he so directs nature as to produce and reproduce the largest amount of the most useful wood on the smallest area possible and with the least expenditure of energy or money. That is the task of the forester and of forest management.

Forestry in a wooded country means harvesting the wood crop in such a manner that the forest will reproduce itself in the same if not in superior composition of kinds. Reproduction, then, is the aim of the forest manager, and the difference between the work of the lumberman and that of the forester consists mainly in this: that the forester cuts his trees with a view of securing valuable reproduction, while the lumberman cuts without this view, or at least without the knowledge as to how this reproduction can be secured and directed at will. The efficient forest manager requires no other tool than the ax and saw—the planting tools being needed only to correct his mistakes—but he uses them differently from the lumberman.

And what are the methods of forest management?

Admirers of European forest management, as well as the knownothings who consider it inapplicable to our conditions, very often confound the administrative features with the technical management.

To cut a given equal amount of wood yearly, as is done more or less strictly in most European government forests, is a purely administrative measure, just as a mine owner may propose to take from his property annually an equal amount of coal. To cut over a certain area and take out a certain number of trees because it is a seed year and we want to take advantage of it for reproduction, and in order to secure that satisfactorily remove a certain amount of the shade—that is a technical measure, just as the proper proportioning of coal and ore and flux to make iron.

The administrative measures in vogue in European forest management we may perhaps not think desirable or suitable to our country and conditions, but the technical measures as far as they are based upon natural laws and proved by experience proper for the object in view will have to be adopted with the necessary modifications if we wish to attain proper forest management.

Before, however, we may apply the finer methods of forestry management as practiced abroad, it will be well enough to begin with common-sense management, which consists in avoiding unnecessary waste, in protecting against fire, in keeping out cattle where young growth is to be fostered, and in not preventing by malpractice the natural reforestation.

REPRODUCTION.

There are three ways of reproducing a forest, which lead to three methods of management. We may either remove the original growth and replant the area, or we may cut it and expect the reproduction by sprouts from the stumps, or else we may so manage our cutting that seed from some remaining trees sows itself and produces a new growth of seedlings. Often any two or all three methods of reproduction may be employed together.

The first method, namely, that of replanting the cleared ground, is simple but expensive, especially in our country, where wages are high. The method is objectionable, also, because by the removal of the original cover the soil is exposed to sun and wind and is liable to be covered by weed growth, which reduces the chances of successful reforestation. It is, however, largely used in the pine forests of Europe with tolerable success, and has the advantage that the cutting may be done without regard to the seed production.

Planting becomes necessary where all original growth is absent, as in the prairies and plains and on the devastated hill and mountain lands, or where, by lack of proper attention in cutting the forest, undesirable species have gained possession of the ground.

The second method, that of reproduction by sprouts from the stump, familiarly known as coppice management, can be used only, of course, with such kinds as will sprout. The conifers, therefore, are entirely excluded, for although a few of them (sequoia, and some pines) do sprout, the sprouts do not develop into trees of size. Altogether, sprouts, while growing rapidly, remain comparatively short. This management is, therefore, only fit for the production of firewood, charcoal, ties, poles, posts, and wood of small dimensions. Most of the so-called second growth of the forests of New England and elsewhere in the United States consists of coppice growth, and does not promise much for future supplies of dimension timber. In time the stocks lose their vitality and the quality of the forest deteriorates.

The third method, that of natural reproduction by seed, together with artificial planting, produces the timber forest.

There are various ways of applying this method; either leaving seed trees scattered over the entire area, or clearing strips and leaving a neighboring growth of seed trees to supply the seed for the reproduction on the cleared strip.

In these methods one is dependent on the seed-bearing of the mother trees, and it must not be overlooked that most or many of our most valuable trees do not bear seed every year, at least not plentifully.

The clearing of strips, with seeding from the neighboring growth, is perhaps the simplest and on that account may recommend itself to the lumbermen. It is applicable with success, however, only to those kinds which have light enough seed to be scattered over the cleared strip by the winds, and which can sprout and develop satisfactorily without the partial shade of nurse trees and grow fast enough not to be crowded out by weeds.

To make this method tolerably effective, the width of the cleared strip should not be more than the distance which the wind is sure to carry the seed, say from two to four tree lengths, according to kind, and that the clearing occur in or precede a seed year.

By reducing the size of the clearings to small openings the chances of successful reproduction are increased; and in this manner we come to the next method, which consists in a thinning out through the entire area that is to be reproduced, and letting in enough light to stimulate seed bearing, proper decomposition of the litter to make a seed bed, and to favor the growth of seedlings. The method of reproduction from seed trees standing on the same ground requires perhaps the least change from our present method of utilizing the forest, which consists in culling out trees here and there. The main changes necessary would be to remove first the undesirable trees and the undesirable species, and to utilize the desirable only gradually after seeding has taken place, and in doing so keep in view the requirements of the young growth for either shade or more light. To do this successfully requires considerable knowledge and judgment, and in fact the art of the forester is here called into fullest requisition. Differences of condition necessitate differences of treatment. It would lead us too far to discuss in this paper at length what is required. I may only briefly recite an example, namely, how the beech forests are reproduced in Europe.

The beech, like many other timbers, bears seed only periodically. Seed years occur in different localities at periods varying from 3 to even 20 years, records of their occurrence being kept. A few years before the seed year is expected to occur the forest is somewhat thinned out to admit air and light upon the soil, in order that the litter of the forest floor be more rapidly decomposed and humified, and so may form a suitable seed-bed for the sprouting of the seed, and also to stimulate the mother trees to a plentiful production of superior seed. In this thinning the inferior material and the undesirable kinds are first removed, and such kinds as reproduce themselves easily without aid from the forester. When the nuts fall, pigs may be driven into the woods to plow them under. Under favorable conditions a soft, green carpet of young beech seedlings will be found to cover the ground in the spring next after the seed year. Now comes the critical period. If the mother trees were left, the whole crop would be lost, and while waiting for the next seed crop, under the altered light conditions which invite grasses, weeds, and other species, the difficulties in securing reproduction are increased. By thinning out gradually the proper amount of light is given to the young crop, and when in three or four years the last of the mother or nurse trees are removed, a thicket of young beeches has replaced the old growth. In a similar manner, with necessary modifications in procedure according to species, climate, and soil, the natural reproduction of other species is effected.

IMPROVEMENT OF THE CROP—THINNING.

Having removed all the old growth and secured a young growth, there follows its cultivation. This consists first in improving its composition and secondly in promoting its rapid and desirable development. Both these objects are attained by proper thinning, repeated from time to time.

The young growth is rarely such as we would like to see. Some undesirable kinds are prominent which should be reduced in number; here are some stumpy and bushy trees which prevent the development of their neighbors and are best removed; there a stump has produced more sprouts than it can support and it is wisdom to thin them out, cutting especially the inner ones. Here is a kind especially valuable that we would protect from being smothered by its less valuable neighbors. There may also be larger fail places in the natural reproduction, and if too large to be covered over in a few years we may deem it desirable to plant such places with some valuable kind.

In this way for the first 10 to 15 years, by judicious use of the ax mainly, we try to improve the composition of our crop. These trimmings must be made carefully, however, so that the soil which is shaded by the crown may not remain exposed for more than 2 or 3 years; that is to say, in that time the crown cover must close itself again. When in this manner the crop has been brought into desirable shape, a series of thinnings follows, repeated periodically or going on continually, as may be most convenient, the object of which is to advance the development of the growth, to hasten the formation of valuable wood. In these thinnings a certain number of trees are taken out in order to give the remainder an opportunity to develop more quickly and with the least hindrance to desirable form and size.

The philosophy of these thinnings lies in the observation that light is one of the important factors of life and especially of tree growth. It is under the influence of light that foliage develops and that leaves assimilate food; the more foliage and the more light at its disposal a tree has the more wood it will form. On the other hand, if we compare trees grown in the dense forest with those grown in the open field, we will note a difference in habit and shape; while the latter, grown in full enjoyment of light, have during the same time attained a greater diameter, have in fact made more wood, the latter excel in the length, straightness, and cylindrical form of their trunks; while the former have developed largely into branches, the latter have fewer branches, and altogether, although having made less wood, have produced a more useful quality.

Hence, in order to produce good timber, which is the principal aim of forest management, dense growth is necessary, when the light, needed for the development of branches, is cut off and a clean shaft the result; yet on the other hand, to produce largest amount of material open position is more favorable.

The whole secret of forest management then consists in so balancing light conditions in the forest that the largest amount of wood possible is formed in the trunk without much branching; that is to say, to secure the greatest amount of foliage on the largest number of individuals that may develop on the areas to best proportions.

UNDERGROWTH.

From the soil trees derive mainly that most needful element of growth, water. It is, therefore, very necessary not only to preserve sufficiency of moisture in the soil, but also to keep the soil in such condition that the rains and snows can penetrate it. This is done by keeping the soil shaded and covered with the natural litter and undergrowth, which checks undue evaporation and preserves the granular structure of the soil so favorable to percolation.

Undergrowth, therefore—not, however, the grass and weeds which transpire more water than their shade prevents from evaporating—should be fostered, and the protection of the soil, especially of poor soil, against sun and wind must also be kept in view in the amount of thinning to be done.

MIXED GROWTH—LIGHT INFLUENCES.

To understand technical forest management, especially the practice of thinning, it is necessary to realize that in the vegetable world, as in the animal world, there is a constant struggle for supremacy going on between the different species as well as among the individuals of the same species. The methods used in this warfare are various, and both offensive and defensive. One species seeks to gain a foothold by prolific production of seed, and perhaps of light-winged seeds which the winds will carry everywhere, like those of the ubiquitous aspen. Another species "shades out" its rivals by dense foliage. Firs and spruces are examples of this class. Others again develop a superiority of the root system, enabling them to endure shade and other privations until the overtopping rivals succumb to the influence of time. The oak is an example of this kind. In this way the alternation of forest growth, so often remarked upon, finds a natural and rational explanation.

Now, the task of the forest manager is to interfere in this warfare in favor of the species which he desires to propagate and have specially develop for his own objects by reducing the chances of reproduction and supremacy of the undesirable species.

Mixed forest growth is the rule in the world; in the natural forest, with few excepted localities, there are usually several species occupying the ground together. The forester knows that there are various advantages resulting from this arrangement, and he fosters the mixed growth, although the management of a mixed forest presents more difficulties and requires more knowledge and judgment than the forest formed of a single species. In the management of both there is, as we have seen, one condition which requires the most careful study and consideration, namely, the dependence of tree growth on light, by which in the forest the ultimate domination of this or the other tree or species is determined.

Especially the varying amounts of light which the different species either need or can be satisfied with,* and also the rapidity with which they grow in height and which gives them a chance of escaping the shading exerted by their neighbors, are of interest to the forest manager.

Go into the dense forest and see what kinds of trees are vegetating in the dense shade of the older trees, and then go into an opening recently made, an abandoned field or other place, where the full benefit of light is to be had by all alike, and you will find a different set altogether occupying the ground and dominating. In the first case you will find, perhaps, beech and sugar maple or fir, and spruce; in the second case you may find aspen, poplars, willows, soft maple, oaks, or pines, tamarack, etc.

All trees thrive ultimately best in full enjoyment of light; the leaves exercise their functions under its influence and feed the tree by assimilating the carbon of the air and transpiring the water of the soil, but some, like those first mentioned, can at least subsist and their foliage functionate with a small amount—they are shade-enduring kinds, they usually have a dense foliage, many leaves, and each one needs to do but little work—and exert considerable shade when fully developed, while those last named can not exist long without a considerable amount of light, having less foliage—they are light-needing kinds.

To offset this drawback in the constitution of these latter nature has endowed them as a rule with the capacity of rapid height growth, to escape their would-be suppressors, but again, what they have gained in the rapidity of development they lose in the length of life; they are mostly short-lived species, while the shade-enduring are generally slower growers, but persistent and long-lived. Some kinds, like most of the oaks, stand between the two; while exhibiting a remarkable capacity of vegetating in the shade, they are really light-needing species but comparatively slow growers and long-lived. One and the same species behaves also somewhat differently under different soil and climatic conditions; for instance, as a rule, the light-needing species can endure more shade on moist soils and the shade-enduring require more light on drier soils.

In the earliest stages of life the little seedlings of most trees require partial shade and are quite sensitive in regard to light conditions. Some have such a small range of light and shade endurance that, while there may be millions of little seedlings sprouted, they will all perish if some of the mother trees are not removed and more light given; and they will perish equally if the old growth is removed too suddenly and the delicate leaf structure, under the influence of direct sunlight, is made to exercise its functions beyond its capacity.

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* See also p. 36 of this bulletin.

Left to itself, as the forest grows up and as the individual trees develop, each trying to hold its ground and struggling for light, there is a natural thinning taking place, some trees lagging behind in growth and being shaded out, until in old age only as many trees remain as can occupy the ground without incommoding each other.

This struggle among the individuals goes on during their entire life. Some few shoot ahead, perhaps because of a stronger constitution or some favorable external cause, and overtower their neighbors; these, lagging behind, fall more and more under the shading influence of their stronger neighbors until entirely suppressed, when they only vegetate until they die, while the struggle continues among the dominant class and is never ended in a forest that is utilized at the proper time by man.

The differentiation into dominant growth and laggards takes place in general earlier and more decidedly on strong soils, also in light-needing sooner than in shade-enduring species, which last keep up an even struggle much longer than the former, so that it is difficult to say which will finally win.

It is to give direction and assist in this struggle, to hasten its results, to obviate, if possible, useless expenditure of energy by timely interference, that the forester steps in with the ax. For the natural thinning, as a rule, does not progress satisfactorily for the best quantitative and qualitative development, and hence it is assisted by the forester, it being well understood that there is a larger total and more valuable product to be had with a smaller number of individuals through better development of the latter.

It is the number of trees that yield the best result, not the greatest number that we try to keep growing. What this best number is depends naturally on the kind of trees; it changes also with age, as the trees need more room, and with soil and situation.

In the average we would not be far out of the way to require per tree in the twentieth year 10 square feet, in the fortieth year, 40; in the sixtieth year, 100; in the eightieth year, 125, and in the one hundredth year 160 square feet growing space, or 4,300, 1,100, 435, 350, and 270 trees per acre, respectively, at the ages noted, would represent about the proper average condition of growth. There are from 50 to 75 per cent more shade-enduring trees possible on an acre than light-needing; more trees on poorer soils, sometimes two to four times as many, than on good soils, and more in the valley, sometimes double that of the higher elevations; so that while a pine growth of, say, 60 years may show 500 trees to the acre, a beech growth may contain 750 trees under the same conditions.

SPECIAL CONSIDERATIONS IN THINNING.

The three questions in thinning which always confront the forest manager are: When to begin and how often to repeat the thinnings; how severely to thin at one time or how many trees to permit to grow; which trees to take out.

These questions of course can only be answered according to the special conditions of each case. As a rule it will be best to begin this series of thinnings when the signs of the struggle for light begin to show themselves unmistakably; that is to say, when a decided difference in individual development can be seen and the dominant growth be discerned from the laggards.

On strong soils and with light-needing species this occurs sooner, and the time for interference is more easily determined; but in these cases assistance is also less urgent than on poorer soils, where more individuals are struggling in an even fight, and usually the separation into dominant growth and suppressed or laggards does not take place easily and early, and here, therefore, it is more needful to give timely assistance.

In practice a consideration for beginning these thinnings is also the possibility of using or marketing the material cut out. But this is a proper consideration only because we do not know yet when it is profitable to spend time or money for thinning merely for the benefit of the remaining growth.

As a rule the thinnings are begun in light-foliaged, rapid-growing trees with the fifteenth to twenty-fifth year, while with shade-enduring species one may wait until the twenty-fifth to thirtieth year; that is, the time when the greatest annual height growth is attained and diameter development is desirable.

The questions how much to cut out and how soon to repeat the operation are somewhat interdependent.

In small wood lots, where the owner uses perhaps the thinned out material himself, a continuous gradual thinning is best, while on large areas it may not be practicable to do otherwise than to subject a larger area to the operation at once and repeat it in a few years. In such a case enough must be taken out to avoid crowding until a second thinning, and yet not to cut so severely as to interrupt the crown cover too long and lay bare the soil.

The oftener the thinnings are repeated the better for the remaining growth. The repetition may be made every 2 or 3 years in pines and rapid-growing soft woods, while in shade-enduring and slow growers every 5 years may be sufficient. Condition of the growth and judgment alone can determine this. The same is true as regards the amount to be thinned out.

I repeat that there are always three considerations to be kept in view and their requirements balanced, namely, conservation or improvement of favorable soil conditions, which requires dense shading, while large yield in quantity requires room and loose position, and trunk development in quality requires moderate crowding.

A study of crown development is necessary to form a judgment as to what is required. Here we have the predominant few, with an exceptionally full crown, while the majority of the trees have only a moderately developed head. We next discern quite a number which have still a normally developed crown, yet form only a subordinate part in the main crown canopy. These three classes form the dominant growth and the active crown cover. Underneath these we find trees with small undeveloped crowns, suppressed, dying, dead. These last classes are, to be sure, out of the struggle, and their removal means nothing to the superior or dominant growth; they may be taken or left as their wood can be made useful or not. The question can only be which of the other three classes to favor and how much to open the crown canopy.

As to the latter question, soil conditions are to be consulted first. On poorer soils less opening is preferable; the same rule is good on steep hills, southern exposures, and where windfalls may be invited by too severe thinning. The age of the growth also has a bearing. Later on, when the principal height growth has been attained and the trunks are clear of branches to a sufficient height, and the formation of clean boles is not any more to be considered, the thinnings may be made severer. As a rule the crown cover should not be interrupted more than the remaining growth is capable of closing up again within 3 to 5 years; this would take rarely more than one-fifth to one-third of the growth if the crown cover was normal at the time of thinning. As to which class to favor and which to remove opinions are at variance just now. The old conservative school permitted the removal of the first or second class only, when either a more valuable kind was threatened to be overgrown and killed out by a less valuable, or when the latter had an abnormally spreading crown, overpowering more neighbors than it could possibly supplant in amount and quality of growth, or when malformed or diseased, or else when a growth showed too large a number of individuals developed equally, in which case the natural differentiation into dominant and overgrown takes too long a time to be accomplished naturally.

The new, more radical school argues that when the time for severer thinning has arrived the foremost trees should be utilized first, because they yield the most valuable material and the next two classes are thus given opportunity to develop still into superior material, which they will do under the increased light influence, and that with more profit than if the stoutest trees had been given further advantages.

In the opinion of the writer this question can not be decided for all cases alike, but species, age, and soil conditions may require one or the other principle to prevail.

In mixed growths it should especially not be overlooked that the light-needing species (like ash, oak, pine, larch) must have much more light than the shade-enduring (like maple, beech, spruce, hemlock) in order to develop at all satisfactorily.

It may be of interest here to state that through the means of thinnings the product per acre in the same time may be increased from three to five times of what the result would be were the forest left to itself.

Enough has been stated in the foregoing remarks to give an idea of what the object and in general the methods of forestry management are. The owner of a small wood lot can apply it to his few acres as well as the lumber king owning thousands of acres; the private citizen and the town or county as well as the State may carry on forest management. Only, as shown before, where, as in extensive mountain regions, a very conservative policy is necessary in order not to disturb advantageous natural conditions of soil cover and water flow, and where on that account forest management becomes more difficult and less profitable, communal or State ownership will be preferable.

EUROPEAN GOVERNMENT FORESTRY.

Contrary to the ideas prevalent in the United States, European governments hold but a small fraction of the forest area and do not control, except in special cases and within certain limitations, the forest property held by private owners. In Germany less than one-third of the forest area is managed by the government, and 19 per cent owned by communities and corporate institutions is under more or less direct control (mostly advisory) of the government. Nearly one-half, therefore, is in private hands and beyond control.

Since, however, much of this private forest area has been held for centuries in large estates, its management is of a conservative kind, and being administered by trained foresters, is often as good and sometimes superior to the government management; the efficient officers of the government frequently aiding, with their counsel, the private owners. In the western provinces and southern states the farmer owns his wood lot in fee simple, just as the American farmer does, but having learned the value of keeping his wood lot in a continually paying and reproducing condition, he reaps from it as regular an income as from his other crops.

In *Austria* not more than 13 per cent of the forest area is under government administration. The sad and disastrous consequences which the reckless devastation and abuse of these mostly mountain forests by their private owners has brought upon whole communities adjoining have lately led to a more stringent and general supervision of the management of communal and private forests by the government than elsewhere. In *Switzerland*, since 1874, the federal government, while owning but little over 4 per cent of the forest area, exercises supervision over the 66 per cent of communal forests. Private forests, when not classed as protective, are only prohibited from being cleared.

In *Italy*, where the government owns only 1.6 per cent of the forest area, a new law was passed in 1888 by which reforestation of the desert mountain lands is made obligatory, the government contributing three-fifths of the cost and expert advice, or else reserving the right to expropriate and reforest on its own account.

The law is drawn in a liberal spirit toward the owners, but with full recognition of the need and justice of restricting the foolish and willful exercise of their property rights, where this is bound to injure the community at large.

In *France* 10 per cent of the forests is held by the government, and 27 per cent owned by communities are under its control. Private property is only under supervision where special reasons can be shown that indiscriminate cutting is dangerous to the community.

In *Spain*, which has perhaps suffered more from the effects of forest destruction than any other country, the state owns only 4.5 per cent, but controls the communal forests, representing 80 per cent, to some extent.

In the *Scandinavian* forests, 15 to 20 per cent of which are owned and managed by government, there is hardly any more forestry practiced than in Maine, where some owners restrict the cutting of trees to certain sizes.

The same may be said of *Russia*. The crown, however, owns about two-thirds of the forest and has begun some management. The private owners are entirely unrestricted, and cut their timber imprudently and improvidently, without regard to reproduction, and, as far as methods of using their forest property are concerned, stand about on a level with the American timber-land owner.

England has practically no forests of extent, only 3 to 6 per cent covered by plantations. Its equable climate and configuration have not made this deficiency felt, but public interest has lately been directed to the profitableness of forest growing on waste places and more attention is being paid to sylviculture. In India the government has established a full forest administration, which nets annually several million dollars.

ADMINISTRATIVE CONSIDERATIONS.

In carrying on forest management on a large scale and over extensive areas there is, as in every such business, need of a well-organized administration, which involves the organization of a service, the preparation of working plans, determining the manner in which the crop is to be harvested and disposed of, the expenditures for desirable roads, and other improvements, etc.

To give an insight as to what government forestry involves, a brief description may be of interest, especially as in several States, notably, in New York, and also for the United States timber lands, forest administrations are proposed.

As far as organization of a service is concerned, this must, of course, vary according to social conditions, and in a State administration, according to political methods; furthermore, according to the size and location of the forest areas and the intensity and thoroughness with which they can or are to be managed and many other local conditions.

Taking the Prussian forest department as an example of a first-class, tolerably intensive forest administration, we find it thoroughly systematized. Each province has a fully equipped separate administration, and all of these are under the general central direction at Berlin.

The latter is connected with the ministry of agriculture and consists of one director and four subdirectors, each acting for a definite section of the empire.

The director, with the advice of the subdirectors, determines the general policy and principles of administration, looks after the personnel and directly after the forest schools, and has practically the final decision on all matters that can not be settled by the provincial boards.

In each province there are two or three government seats, and at each seat there is a local direction, inspection, and control under one director, the over-forestmaster, with a number of forestmasters to assist him, each of these being charged with the inspection and control of the administration of a number of forest districts.

The latter, being forest areas ranging at from 5,000 to 30,000 acres in extent, are under the direct charge of the resident local managers (Oberfoerster), who are directly responsible for the execution of working plans and everything connected with the management of their district. Under their command there are a number of foresters, each in charge of a subdistrict, to act as guards and to superintend the work in the forest. This force is increased by guards temporarily employed and by numerous aspirants for positions, who are also temporarily employed as assistants.

All money transactions involving cash are carried on through the agents of the treasury department, upon the draft of the district manager with reference to the particular position provided in the working plans, so that no forest officer handles any money.

There exists also at the central direction a special bureau for revision of working plans.

In this way, for the forest property of about 6,000,000 acres belonging to the state of Prussia, there are employed, besides some clerks, etc., nearly 5,000 officers, namely, 5 directors, 125 supervising inspectors or controllers, 680 resident managers, and 4,000 foresters and guards, nearly 900 of this number having received a high technical education, the total cost of this service being about $2,500,000, or 34 per cent of the total expenditure, and not more than 20 per cent of the gross receipts.

WORKING PLANS.

In making up working plans for a large forest area, considering the fact that the crop matures only in 60 to 150 years, more or less, it stands to reason that a general plan for the whole time of production and a special working plan from year to year is necessary. And in planning both technical and financial considerations must be consulted.

For a forest administration on a large scale, and especially for a state forest administration, the management should produce from year to year about the same amount of revenue and involve the same amount of expenditure.

Especially is it desirable, although technically by no means necessary, that neither less nor more wood be cut than grows annually, so that there is a continuous production of about the same amount forever.

To determine what that amount is requires a considerable knowledge of the conditions of the forest and the rapidity with which the annual wood growth accumulates.

As stated before, it is not wood, but wood of certain quality, and the largest amount at least expense per acre, that forest management is after. Now, the quality as well as the greatest quantity of wood is to be found in a tree of certain age, and while this age may vary for different kinds of trees and different localities, it is approximately determinable when it is most advantageous, alike for quality, quantity, and cost of production, to cut the tree or the forest. The time from the seedling stage to the mature tree ready for the ax is called the "rotation." If we say this pine forest is managed under a rotation of 100 years, it means that we allow each tract to grow to 100 years before we cut the trees, or that we expect to return for a new crop within 100 years to the same acre we have just cut. Now, if we desire to cut an even amount every year, say, for instance, one acre of 100-year-old pine, we would need to have 100 acres of pine, each acre differing in age by 1 year.

This would be an ideal or normal forest, in which we also suppose an equal annual normal accretion. In such a normal or ideal forest there must be at the outset a certain amount of wood standing, which is the stock upon which the yearly accretion accumulates, and may be called the normal stock or normal reserve. It consists, of course, of the sum total of wood on each acre from the 1-year-old to the 100-year-old, and its amount is readily figured out if we know the difference in amount of wood between each acre or the normal accretion per acre from year to year; for it is one-half this amount multiplied by the number of acres, or what is the same, the years of rotation. In our example, for instance, with a pine forest, which we work under a 100-year rotation, if we assume that there is an annual normal accretion of 50 cubic feet per acre, the normal reserve would figure $100 \times 50 \div 2 = 2{,}500$ cubic feet per acre. This, then, is the average amount per acre which we should strive to keep in stock in order to insure an equal annual amount of growth or an equal annual cut.

In reality this ideal of course is never reached, but it serves as a guide in the working plans, and the conception is a most important and useful one.

Thus in bringing a mismanaged forest growth under management for continuity we may find the stock of reserves to be either above or below the normal, and hence we may either cut more or less than the normal accretion, until the reserves are brought down or up to or near the ideal.

The working plans must also include the propositions for improvement for new cultures on denuded areas, etc. One of the most important improvements is the construction of properly situated and well-kept roads or other means of transportation. In European forests the "road net," as a rationally disposed system of roads is called, is considered of prime importance. Accessibility to markets, easy, cheap, and permanent means of transportation furnish the keynote of profitable forest management.

The method of marketing the crop is another matter of administrative consideration. This can be done either by selling the crop on the stump or by shaping it and placing it on the market either in the woods or in the stores.

To the first method there is considerable objection for the reason that in cutting for reproduction there is need of careful handling of the timber, and it requires much undesirable supervision if private parties do the logging, while the administration, logging on its own account, can better control the manner in which it is done. In most European administrations the cutting is done by the administration; each log is measured and numbered and each cord is also numbered, and after public announcement the wood cut in a certain district is sold at auction by numbers to the highest bidder, lumbermen and other wood consumers having an equal chance.

The surveying and mapping and the districting, manner of employing labor, leasing privileges, etc., are other administrative matters.

This will be enough of the principles and detail of forest management to give an idea of what it is and what it involves.

PROFITABLENESS OF FOREST MANAGEMENT.

The question whether forest management is profitable can no more be answered in general than the question whether agriculture or any other business is profitable. It depends upon many conditions which differ in each case.

Broadly speaking, when we consider that the forest occupies or ought to occupy ground that is not good for anything else, that after being started it grows without involving work, except such as yields valuable material, it will be conceded that the small exertion necessary to prevent the soil from being laid waste or occupied by inferior brush must be well repaid.

There are examples enough to be found in the United States where even forest planting in a small way has proved profitable; forest management on a large scale does not as yet exist.

To show what the financial results of management on a large scale are abroad, it may be of interest to add a few illustrative statistics, and it will be especially noteworthy in these what wide differences in expenditures and results there are to be found over so small a territory. These differences are due to differences of market facilities and intensity of management and also to forest conditions.

Countries.	Forest area.	Total expenditure.	Revenue.		Expenditures and revenues per acre of forest.						
			Gross.	Net.	Expenditures.						Net revenue.
					Total.	Per cent of gross income.	Administration and protection.	Marketing crop.	Cultivation.	Roads.	
	Acres.										
Prussia	6,000,000	$8,000,000	$14,000,000	$6,000,000	$1.33	58	$0.48	$0.30	$0.14	$0.06	$0.96
Bavaria	2,300,000	3,150,000	5,880,000	2,730,000	1.37	53	.64	.37	.11	.11	1.19
Würtemberg	470,000	1,025,000	2,260,000	1,235,000	2.17	45	.87	.92	.22	.33	2.63
Saxony	416,000	1,040,000	2,750,000	1,710,500	2.50	37	.65	.81	.11	.21	4.11
Baden	235,000	404,000	1,090,000	686,000	1.54	40	.22	.83	.15	.12	2.90
City of Zurich	2,760	14,000	26,000	12,000	5.00	54	1.14	2.10	.16	1.14	4.40

In fourteen state forest administrations of Germany, covering 10,000,000 acres, the cut during 10 years was 55 solid cubic feet per acre per year, of which 27 per cent, or about 15 cubic feet, was lumberwood, equal to about 120 feet board measure.

Figured on such basis of 55 cubic feet of normal annual accretion and a rotation of 80 to 100 years, the total normal wood reserves on these state forest lands would be in round numbers 24,750,000,000 cubic feet, worth, at 5 cents per foot, the average stumpage value, $1,250,000,000. The net income from these lands averages $31,500,000, namely, $29,000,000 for wood and $2,500,000 for other uses, or $3.15 per acre, or only 2½ per cent on the value of the wood reserves figured at $125 per acre. From this it will be seen that a considerable amount of capital is tied up in the wood reserves and brings only a moderate income. On such a large area, to be sure, there are many parts that produce but little and which depress the general results, areas which are managed for cultural and economic reasons and for the protection of watersheds, but which do not produce such revenues as would tempt the majority of private men, and hence the more reason for state ownership of these.

That, however, it is more profitable than otherwise to the farmer to keep his wood lot in fair producing condition, and to the timber-land owner to avoid all wasteful use of his property which prevents natural reforestation must be as patent as that a herd of cattle producing calves is more profitable than one which is barren.

[There followed in the original address, of which this paper forms a part, a discussion of the problem now before the State of New York of reserving the Adirondack forest lands as a State domain.

The proper organization, involving an expenditure of $400,000, or 18 cents per acre as against 48 to 87 cents in German states, and the net financial results were stated. It was shown that the stumpage of the 2,500,000 acres to be reserved would be worth now $25,000,000, and that an annual net income above expenses of administration and improvements of over $1,000,000 should result from a conservative management.]

III. FOREST PLANTING IN A TREELESS COUNTRY.

To see the prairie and the plains is to know their needs. To travel over them, even for a day, will make you feel their greatest want—the want of trees. Wind swept every day, every hour, the comparative calm which even a single row of trees creates affords relief from the perpetual activity of the air beyond the influence of the wind break. Man, beast, and plant are constantly being dried out; evaporation can hardly keep the thirsty, ever-moving atmosphere supplied with moisture, and many a rain only touches the ground to be at once evaporated and returned to the clouds.

The "treelessness" of the central plains has been explained by the deficient rainfall and consequent arid conditions of these localities, and until lately it has been doubted, and even now there are people who doubt the possibility of growing trees and forests in those localities without irrigation.

For a large part of this region I do not share these doubts, nor do I believe that original aridity alone accounts for the condition in which we find this large region at present. As everything in nature is the result of a complication of conditions, so we may not dismiss such a phenomenon as a forestless area of several thousand square miles with the simple explanation that it was too dry for tree growth. The fact that this area is not absolutely treeless goes far to support the proposition that it was not always forestless; and the mining of pine timber out of the sand hills of Nebraska proves the proposition beyond doubt for that section at least.

It is not the speculation of mere curiosity to inquire into the causes of the absence of forests in this region; it is a practical question; for if we understand the causes which produced the present conditions we gain an insight into the possibilities of remedying them; we may learn whether nature decreed that this area shall forever be exposed to the heating of the sun and sweeping of the winds or whether we may reasonably expect to cover its nakedness, and what are the difficulties in the way; we shall have a basis for our methods in the attempt to reclothe these areas with forest growth.

The entire earth may be said to be a potential forest. That is to say, if the interference of animal life and man were excluded in the struggle for existence among the different forms of vegetable life, wherever sufficient depth for its roots exists and winter cold does not preclude it, arborescent growth would ultimately prevail on account of the perennial character of this kind of vegetable life and its power to shade out the lower vegetation. In a large part of the world this victory is seen to be attained in a few years, or at least in a lifetime. In other parts it may take geological ages to establish the arborescent growth against the lower vegetation and against unfavorable climatic conditions. Such are mainly the interiors of large continents and those localities which, for cosmic and orographic reasons, have a climate unfavorable to vegetation in general. This unfavorableness, as a rule, is mainly to be found in moisture conditions—not necessarily deficient rainfall, but an unfavorable balance between the factors of conservation and of dissipation of moisture. In such localities the progress of the forest growth contending for supremacy must be a gradual advance from the more favored border land, but the extension of its area, if not interfered with by man and beast, though slow, is as certain as in the more favored localities, where it proceeds rapidly.

It is conceivable, then, that while admitting the unfavorable rainfall and moisture conditions in parts of this region as a potent cause in making forest extension difficult, this extension would yet have taken place if fire and the tramp and browsing of buffaloes had not prevented it; or, since the scattered tree growth found on this area suggests that forest growth once existed, it would now exist if fires had not destroyed much of it, thus disturbing the conditions which were favorable to the conservation of the scanty moisture, reforestation being prevented by continued fires and countless herds of browsing and soil compacting buffalo.

Where, during the months of vegetation, May to August, the relative humidity of the air sinks as low as 50 per cent and the rainfall is less than 2 inches, it may be questioned whether tree growth could maintain itself before the conditions of the surrounding country have been in a measure modified; or unless we may be able to find and introduce species not native, which, like some of the desert trees, the tamarisk, for instance, can exist for several years without rainfall.

There is a very peculiar and intimate connection between vegetation (especially forest vegetation) and climatic conditions. Most naturalists will tell you that vegetation depends upon climate. So it does; but there is also a reaction of vegetation upon climatic conditions, and this truth is strikingly expressed by the poet, who speaks of "Africa's arid sands, where nothing grows because it does not rain, and where it does not rain because there nothing grows." This sounds like a paradox, and yet it is true; there is such a relation between the forest cover which shades the ground, and the changed temperature and water conditions of soil and air under its cover, as to favor its own development, so that we can say "the forest creates its own favorable conditions of growth." But it is not the single tree that has such an effect, nor a few scattered trees; it is by effective shading of the ground that the change of conditions under the forest cover is brought about, it is by masses of trees that the sun's power is broken, and it is by large areas distributed over the vast expanse that ultimately the force of the winds will be broken.

I can not too strongly impress you with this idea, that it is a mass effect which we expect from the forest cover. Not only will our plantation be more successful if we start it with this idea fully before us, that it must create "its own favorable conditions of growth" and soon become selfsupporting, but its effects upon the surroundings will be more readily felt the denser, the larger it is, and the closer the neighboring plantations which add to the general effect. Where the single tree perishes the forest may live; here, too, "in union is strength."

FOREST COVER AND MOISTURE.

For a large part of this now almost treeless area moisture conditions will not necessarily be a check to tree growth.

We know by experience that a naked soil loses by evaporation more than six times the amount of moisture that it would under the shade of a forest cover. Hence, if we have once established a proper forest cover, if we have succeeded in effectively shading the ground by either the foliage of the trees or the litter and mulch of the decayed leaves, and a check to the sweep of the winds, the amount of water available for the tree growth is increased in proportion. What we must never lose sight of is the fact that evaporation is the great dissipator of moisture, and that a dense shady forest growth reduces this evaporation.

I must stop long enough to point out what evaporation means to the arid or subarid, or, shall I say in deference to my friends who do not want to be regarded as quite dry, subhumid regions. If we compare the rainfall during the season of vegetation in eastern and western stations, it appears that there is not much deficiency, if any, during that season on our western plains, and quite sufficient if evaporation were not such a rapacious robber. This enormous amount of evaporation is not alone due to heat and direct insolation, but mainly to the constant movement of the air, the incessant winds which take up and disperse the moisture.

From the interesting experiments recorded in the annals of the Weather Bureau the dependence of the rate of evaporation on the velocity of the wind has been established. With the air at a temperature of 84 degrees and a relative humidity at 50 per cent the evaporation under a wind of 5 miles an hour will be 2.2 times as rapid as in the calm air, at 10 miles 3.8 times, at 15 miles 4.9 times, at 20 miles 5.7 times, and with a wind at 25 miles velocity the rate of evaporation will be 6.1 times as great as in the calm air. And as the average velocity of the wind on the plains may be set down as 12 miles an hour, there is probably at least four times as much water evaporated and dissipated as where the winds are checked. Hence the value of the windbreak which reduces both the evaporation from the soil and the transpiration from the plant, for transpiration is also accelerated by the motion of the plant under the influence of wind.

The hot winds, which are equally as characteristic of this forestless region as the blizzards, sap the moisture out of the soil as well as out of plant, beast, and man, for both are dry. It is summer drought as well as winter drought that we have here to contend with; and since at least the hot winds have been proved to originate within this very region (see a very full paper on the "Hot Winds of the Plains," by George E. Curtis, Kansas State Board of Agriculture, report 1890) and are undoubtedly due to its nakedness, we come to the conclusion that forest cover will not only check the sweep of these winds and thereby the excessive evaporation, but the very cause of these winds may eventually be wiped out.

What do we learn from these considerations to help us in forest-planting on the plains? Plainly at least these two propositions:

(1) That forest plantations in large blocks have more chance of success than small clumps of single trees, since large plantations alone are capable of becoming self-sustaining and of improving their conditions of growth by their own influence upon moisture conditions of the soil and air.

(2) That we must not only plant densely—much more densely than is the common practice—but in the selection of kinds give predominance to such as are capable of quickly and persistently shading the ground, creating an undergrowth and cover that will prevent evaporation and thus make the planting of the light-foliaged, quick-growing valuable timbers possible.

NEED OF COÖPERATIVE ACTION.

I can not here refrain from expressing my sympathy for those in the front, who struggle to conquer single-handed these vast and fertile but climatically ill-favored regions. While their reclamation certainly does not appear to me an impossible undertaking, it seems almost hopeless to expect it from the pygmy efforts of the pioneer settler, lost almost in this endless treelessness.

Without means, without knowledge, without a systematic organization, without a well-conceived and methodically executed plan, without coöperative effort in close battle front, victory, if attainable, must be bought by many repulses, disappointments, failures, and even those that might gain a firm foothold may in the end succumb, because their neighbors failed to support their flanks.

I believe that forest-planting is one of the necessary requisites to permanently reclaiming this vast domain; I believe that reforesting this large area, deforested by fire, buffalo, and consequent desiccation, is not impossible. But I also believe that success can be forced only by coöperation, by a well-conducted army, attacking the enemy under a comprehensive plan, systematically and methodically carried out by generalship, commanding knowledge, means, and power, such as a government alone, be it State or General Government, can command. The present plan of allowing the skirmishers to waste their energy, their lives, is cruelty and bad generalship.

HOW TO PLANT.

Volumes might be written on the proper methods of forest-planting on the plains. I shall confine myself to only one chapter, and of this give only the merest synopsis, namely, the one on the selection of species for planting, with reference to the preservation of soil humidity. For in this chapter we learn the difference between tree-planting and forest-planting, a difference which I fear has not found much consideration by nurseyman and planters.

To establish forest conditions must be the first aim of the forest planter.

Forest conditions, as we find them in the natural forest, consist in dense growth, mixed growth, undergrowth. By so much as any one of these conditions is deficient or lacking, by so much is the forest short of the ideal. Reduced evaporation is forest condition. Shade reduces evaporation. Dense growth furnishes not only straight clear timber, but shade. Mixed growth alone can preserve a continuous shade for a long time. Undergrowth assists in keeping the ground shaded.

The forest planter, then, may learn a lesson from nature in recognizing these conditions as desirable ones and worthy of imitation; but he will also not forget that man is wiser for human ends than nature; that he works with an object which nature does not recognize; that he must intelligently improve on nature's methods to reach his own end, which is the economical production of material or conditions. The value of time, which is no factor in nature's calculations; the value of land, of which nature has an abundance, make it necessary for man to intensify his methods. Thus he will reduce the dense growth from the maximum of nature's planting to the "optimum" (most favorable) of most rapid and plentiful production; he will substitute for the chance mixture of species, which in the natural forest is the result of a free fight for existence among the different occupants of the ground, a combination which is chosen with intelligence and to produce the most desirable results in the shortest time.

In this selection from among the species which are capable of thriving in this locality and soil, and which are yielding the most desirable material, three points must guide the planter:

(1) Their relative capacity for preserving and increasing favorable conditions;

(2) Their relative dependence for development on light and shade;

(3) Their relative rate of height growth.

RELATION OF TREE GROWTH TO LIGHT.

The first point is possessed in the highest degree by the evergreens and by those deciduous trees which have a dense foliage and preserve it dense through all time. There are not many of these latter, for a large number which in their younger years have a full foliage thin out with increasing age. Besides, by the suppression of the lower branches, which are not capable of living under the shade of the crown, the latter is removed farther and farther from the soil, and lateral crowding also kills out many individuals; so that with all this, sooner or later (according to species and soil conditions), the crown cover is more or less broken, and weed growth, rapid humification of the litter, and increased evaporation is the consequence; *e. g.*, all the cottonwood plantations outside of the wet bottoms. The same deterioration of the soil will be noticed under the ash and the black walnut, which thin out rapidly. Soil conditions will, to be sure, modify this capacity of retaining a dense foliage, and on a fresh deep soil even the thinly-foliaged trees will carry a fuller crown.

It is a matter of observation that as a rule the trees which preserve a full dense crown are the ones which are capable of thriving under shade, or at least with less light than the thinly-foliaged ones; thus, a yew, a spruce, a box elder, a beech, will thrive under shade where a pine, a birch, or a locust can hardly exist. There are some exceptions, and some of the thinly-foliaged trees, like the oak, can vegetate though not thrive under the shade of some "foregrown" tree. In fact, one may, according to the different degree of light which is necessary for a thrifty development, range the species so that those at the top of the scale may be called light-needing and those toward the bottom shade-enduring.

I do not want to be understood that any of our forest trees thrive better for being shaded. Excepting in their earliest stages, when protection against heat and cold, rapid evaporation and transpiration, is needed by some, they all grow best in full enjoyment of sunlight; in fact, the rapidity of their development is proportionate to the amount of foliage which is at work, and this again depends upon the amount of sunlight at its disposal. But some can get along with less sunlight; they can endure without much detriment a more or less dense shade for a longer or shorter period, while others, under the influence of their own crown even, thin out soon, and, if shaded by neighbors, are arrested in their growth and killed sooner or later. The time when the influence of light conditions is most potent varies with different species and according to the site, so that, for instance, on a rich, moist soil a light-needing species like the birch will endure for a long time considerable shade, which on a poorer soil would have proved detrimental.

As a rule you will not find among the undergrowth of our forests any species that is a light-needing one. Hence culling any of our thinly-foliaged light-needing trees, such as the white oak or tulip tree, means killing it out, since it can not reproduce itself and thrive in the shade of its foregrown companions.

It is evident that favorable soil conditions can be preserved only by a persistent close crown cover, such as the leafy species furnish. It is, however, not necessary that the crowns should all be on the same level, all of one story, so to speak; on the contrary, a denser cover can be secured if individual trees or groups of varying heights are placed together. Here, then, comes in the consideration of the relative rate of height growth. And it is an important one when we select a mixture or combination, for if we were to place together on an equal footing a light-needing with a shade-enduring kind, of which the latter is a more rapid grower, the former would soon be killed out. Now, as a rule, the light-needing species—but by no means all—are at first more rapid growers in height than the shade enduring; but what they gain in initial rapidity they lose in persistency; that is to say, they do not grow to as great a height as the leafy kinds, or at least after the first period of rapid growth they grow only slowly.

Each species has its characteristic curve of height growth, characteristic especially in regard to the beginning of rapid ascent, to the position of the points at which the rates of growth change and to the point of culmination. This curve is, of course, modified for each species, according to the site upon which it grows. But as it is possible to construct a scale in which the various species can be ranged according to their relative capacity of shade endurance, so for given conditions and periods of growth they can be ranged in regard to their relative rate of height growth. In this way I have, for instance, ranged twelve kinds that are used in prairie planting according to their shade endurance and their rate of height growth during their youth:

As to shade.	*As to rate of height growth.*
1. Box elder.	1. Cottonwood.
2. Mulberry (?).	2. Soft maple.
3. Elm.	3. Elm.
4. Black cherry.	4. Locust.
5. Osage orange.	5. Honey locust.
6. Catalpa.	6. Black cherry.
7. Soft maple.	7. Catalpa.
8. Locust.	8. Osage orange.
9. Honey locust.	9. Box elder.
10. Black walnut.	10. Black walnut.
11. Ash.	11. Ash.
12. Cottonwood.	12. Mulberry (?).

This is not an immutable scale, but only a tentative proposition, and for the purpose of illustration in which the kinds placed widely apart will alone really retain their relative positions. We will find at the top of the first scale the most shade-enduring and at the head of the second scale the most rapid growers among those named. If we can make, therefore, a combination of these, we will succeed in obtaining the two points to be gained, the densest crown cover in varying tiers, and the light-needing kinds overgrowing the shade-enduring, which allows the largest number of individuals on the area.

I must once more caution you against accepting the above scale as definitely correct. Many conditions of soil and climate modify the behavior of trees. For instance, the black walnut has a tolerably dense foliage when quite young, but except on rich bottom lands it thins out very soon, and, since it leaves out late in the season and loses its foliage early in the fall, it must be considered as one of those which do not furnish desirable shade conditions. In regard to its height growth, too, it may vary; but, as far as my observations go, while it shoots up rapidly at first in the prairie, it almost stops growing when 12 or 15 years old. On the whole we must study the behavior of our trees still further before we can speak with assurance as to the best selection and combination. But we can formulate the principles upon which proper selection and combination rests, and having then concluded never to plant one kind by itself—which is the unfortunate practice in most prairie planting—nor to plant several species in combination without knowing why they should be combined, we can lay down the following rules for making the selection:

HOW TO MIX.

Rule 1.—The main growth, *i. e.*, the one that occupies the larger part of the ground, must be of a kind that improves soil conditions, namely, a densely foliaged, shade-enduring kind, which does not lose its shading capacity with age.

Rule 2.—Densely foliaged kinds may be grouped together, if the slow grower will endure the shade of the rapid grower, or can be protected against its supremacy by being planted in larger specimens, or in advance of the former, or in larger numbers, or if its gradual killing out after it has served its function of soil cover is not objected to.

Rule 3.—Thinly foliaged kinds should never be grouped together where soil humidity is to be preserved, unless no leafy tree can be found to fit the locality.

Rule 4.—In grouping light needing with shade-enduring kinds, the former must be more rapid growers or must otherwise be given an advantage.

Rule 5.—The mixing in of the thinly foliaged trees is preferably done singly and not in groups, unless special soil conditions necessitate the latter method.

With such rules and considerations in mind, the proper practice in prairie planting is indicated.

The first and main object to be attained there is to create a soil cover. In Russia, under very similar conditions to those of our prairies, it has become the practice to first plant a shrub of little or no value—a low willow (*Salix pruinosa*)—as a first soil cover or undergrowth into which the desirable forest trees are planted afterwards. As this can be done only by hand labor, it is not a suitable practice for our conditions. We might use the common bullberry (*Shepherdia argentea*) for such an undershrub, or the sand plum, which I know has done good service as undergrowth. But we have in the box elder, or Russian mulberry, or Osage orange (objectionable on account of thorns) sufficiently hardy and shady kinds, and not entirely devoid of value for their wood, that can be used for the purpose. Of these not less than 6,000 to 8,000 plants should be set to the acre, making rows 3 feet apart and 2 feet in the row; even 10,000 would not be too many, for rapid shading of the ground from the influence of the sun and wind is the key to success.

Any more valuable timber that is to be planted must be as fast a grower as or faster than the underwood and can be introduced at the same time, setting the plants in the same rows at the ratio of not more than 200 to 300, or every 12 to 15 feet, alternating in the rows. For this planting the very best rooted stock should be chosen: Black locust, honey locust, catalpa, and the oaks, and special care taken in planting it. In deeper, specially favorable situations, the black walnut would answer for this selection. The black cherry also promises to be a most valuable addition. Of course a great many variations may be suggested.

CONIFERS.

Of all trees, the most suitable for prairie planting and for planting in the dry plains are beyond doubt the conifers, and especially the pines.

There are two reasons why they should be chosen preferably to others. First of all, they furnish not only a denser cover, lateral and vertical, but a cover all the year around, being evergreen. Secondly, they require less water, from one-sixth to one-tenth of what most deciduous trees transpire, and are, therefore, less liable to succumb to drought. In winter they will hold the snow more efficiently than the naked, leafless kind, thus preserving the moisture on the ground.

Nature has given us indications in that direction. The driest soils everywhere are occupied by the pines, and the arid slopes of the Rocky Mountains and the interior basin support only conifers, especially pines and juniper. From Professor Bessey I learned only to-day that my theory regarding the former forest cover of the plains is borne out by the discovery of pine forests buried in the sand hills of northern Nebraska, and that he found the same kind of pine naturally growing in eastern Nebraska, which covers the Black Hills and Rocky Mountain slopes, namely, the bull pine (*Pinus ponderosa*).

I am also assured that in artificial plantings, after the pines are once established, they rarely succumb to the severities of climate in Nebraska; and I have certainly seen young seedlings of the bull pine thrive most wonderfully in a dense growth of weeds and grass at Franklin, Nebraska, where Mr. C. S. Harrison is the pioneer of conifer growers.

The difficulty in their use lies in starting the plants; for as little seedlings they are remarkably tender, especially as regards light conditions. Under strong light their foliage transpires more moisture than their roots can supply. On the other hand, if left in the nursery until they have developed the strong root system they need, difficulty in transplanting is experienced, and the greatest pains must be taken not only to preserve the roots uninjured, but to bring them into the ground before they have a chance of drying out.

Yet I believe all pains in this respect will be crowned by success, and if I were to direct planting in Nebraska I should use largely the bull, the Scotch, and the Austrian pines, with the Douglas spruce, and for undergrowth the hardy and shady juniper; the Scotch and the Austrian pines mainly because they can be had more cheaply than the others, and because so far they have been tried the longest with assured success. This list may no doubt be extended to others (such as given in the foot-note below.)*

OTHER CONSIDERATIONS.

Besides the capacity of shading the ground effectively and of developing satisfactorily in mixture, other considerations which should influence the selection of plant material are adaptability of the plants to climate and to soil, root system, ease of propagation, utility, etc.

The first two considerations, namely, the possibility of the plant to live in the situation in which it is placed, are matters of course.

As far as climatic adaptation is concerned, nothing but trial will answer the question. Since we found that the bald cypress, which occurs naturally in the swamps of the humid Gulf States, was the only class of seedlings that withstood the drought of a Texas summer two years ago, and since we are informed that the bull pine, which covers our most arid plateaus and mountains, suffers from drought in Germany, and the hardy green ash from frost, we may admit at once that we know but little as to climatic adaptation, and trying is our only method of determining.

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* At the present writing an experimental planting with ten kinds of evergreens and six kinds of deciduous trees in varying combinations has been undertaken under direction of the forestry division in Holt County, Nebraska, on the sand hills of that region. The evergreens used are: Bull, Banksian, red, white, Scotch, and Austrian pine, Engleman and blue spruce, Douglas fir and arborvitæ. With these are mixed the following deciduous trees: Locust, box elder, cherry, birch, hackberry, and red oak.

There are planted four plats of different mixtures and distances, with from 6,200 to 10,830 plants per acre, the wider planting to be cultivated, the closer to be partly mulched, partly left to itself for the sake of comparing the three methods under exactly like conditions. The planting (in the loose sand with good supply of subsoil moisture) was done in furrows without previous preparation of the soil. Planting with the spade or other tool without any plowing would also have been tried had time and opportunity been favorable.

This much, however, may be maintained, that seeds procured from driest and coolest localities in the range of the species promise seedlings of greater hardiness than those from the more humid and warmer climates.

We need in our treeless regions several arboreta for trials, carefully conducted, of adaptation of new kinds.

The list of trees which have been tried and found capable of more or less extended use is already quite considerable and includes the following: Of conifers, white cedar, white, red, Scotch, Austrian, and bull pine, Douglas spruce, and farther south red cedar and bald cypress. Of deciduous trees the hardiest seem to be white and green ash, white elm, white and yellow birch, box elder, soft maple, basswood, besides the cottonwoods, Lombardy poplar, and white willow; and as we go southward the choice increases with black locust, catalpa, mulberry, black cherry, walnut, some oaks, chestnut, with the further addition of honey locust, Osage orange, pecan, and lastly acacias and eucalyptus in the extreme southwestern latitudes.

As regards adaptability to soil, we need consider only the physical conditions of the soil, for forest trees require such small amounts ot mineral matter that it is questionable whether a soil could be found that does not contain in sufficiency those that seem necessary.

Of physical conditions, it is especially the depth, the grain, and moisture that determines adaptability of kinds. While we may say that all trees will grow best on any soil which is deep (that is, where no impenetrable layer of rock or hardpan or soil water is to be found within, say, 3 to 6 feet of the surface), of medium grain (not so compact that water and roots can not easily penetrate, nor so loose or coarse-grained that it can not hold water), and with an even, continuous supply of water, there are some trees which can thrive under less favorable conditions.

This adaptation is probably due to the development of the root system of these trees, but at the same time no doubt to the amount of water required by the foliage to satisfy transpiration.

For planting in the dry regions no doubt those kinds recommend themselves which develop naturally a vigorous root system into the depth, because this enables them to utilize the percolating moisture through a longer space of time and over a larger area. The black locust and catalpa, black cherry, the oaks and maples, and the pines, with a number of other conifers, have such root systems as to insure success where more shallow-rooted kinds would fail.

It would lengthen this paper beyond the bounds of the present intention were I to attempt to discuss in detail the merits and demerits of those species which have proved themselves so far adapted to use in these regions, and still further of the many which still await trial. Suffice it to admit that this chapter needs still much more material, derived from experiment and experience, before we can finish it.

METHODS OF PLANTING.

One word as to the method of planting. I do not think that we have by any means found the best, cheapest, and surest way of planting, and experiment in that direction also would pay. The well-recommended method of breaking the sod in June and plowing thoroughly in the fall for planting in the following spring is open to several objections, among which not the least is the time and expense of this cultivation.

I should propose, for trial, to simply break the sod in June and sow millet or oats thickly to make a close stand; this will secure a return for the labor of breaking. The millet should be cut with a high stubble, which may be expected to catch the winter snow, keep down weed growth, and act as a mulching the next season.

Plant next spring, as early as possible, in trenches, without disturbing the ground between trenches, and most likely cultivation will not be necessary the first season, while the second season, with our dense planting, the trees should be able to help themselves. In this manner I would expect to reduce the work, and also to reduce evaporation and to secure the maximum of moisture in the trenches, where it is most needed.

Let it not be overlooked that there is this difference between a tree crop and an agricultural crop: The latter we want to stimulate as much as we can to produce the utmost in one season, while the former we only want to establish. Thorough cultivation no doubt does this effectively, but is it the best and the only method?

It also stands to reason that what is best to do under one set of conditions is not so under another set. While in the sand-hill region of Nebraska, with a moist substratum at 6 to 12 inches, we had much better leave the ground undisturbed for the reason that it has the tendency to blow out, and on the other hand its capillary conductivity is such as not to favor evaporation from below, a heavy loam, which is apt to bake, shutting itself against ready percolation of water from above and conducting the subterranean supplies to the surface and dissipating them, necessitates some method to keep its granular structure more favorable, either by cultivating or, much better, by mulching.

Certainly systematic experiments in the method of forest-planting are now at least as much needed as in the selection of trees.

The mechanical tree-planter, of which I exhibit an illustration, has proved that you can go even on the raw prairie and start a successful plantation by setting the trees in trenches, leaving the rest of the ground undisturbed, the precipitation draining into the trenches.

FOREST PLANTING A WORK OF INTERNAL IMPROVEMENT.

I do not wish to conclude without suggesting some practical application of my remarks which it would be well for such a body as your State board to consider.

If I am right in believing the establishment of forest belts in your State an indispensable aid to permanently successful agriculture; if I am right in assuming private efforts in this direction unavailing or at least accompanied by much waste of energy and time; if the climatic amelioration which comes from a systematic disposal of such forest areas is a matter which concerns the general welfare of your State, then I contend that it must be a work of internal improvement which it is the duty and function of the State to undertake.

It may not be the present policy of the State of Nebraska to look after the needs of internal improvement—even the United States does but little in that direction,—but the time is not far distant when we shall have a higher conception of the functions of the State than to consider it merely a policeman; when the State, the coöperative association of all citizens, will do whatever is desirable for the general welfare, and what, if left to private enterprise, is not done, because impossible for the single individual, or directly unprofitable, or leading to undesirable monopolies.

Forest planting for climatic amelioration in Nebraska will eventually be one of those public works, and your State board could even now do nothing better for forestry than to formulate and advocate a plan for public forest planting. Such work, such State action I do not conceive to be carried out on the "paternal" plan, although even this would be better than the present inactivity, but it can be carried out on purely business principles. After the general plan has been elaborated, let each county by a commission of competent men designate the areas that ought to be put into forest, and the areas should be as far as possible nonagricultural, the poorest soils. Let the State exercise its right of eminent domain and withdraw such lands temporarily from the ownership of the individual for purposes of public utility and transfer it to the county, the latter taxing itself for the interest and funding on this expenditure as also on the expenditures by the State for planting, etc.

Where the county is still too thinly settled to sustain such a charge, the State may well distribute the interest and funding charges in such a manner that they are made proportionate to increasing population.

Let the State by its own officers, under direction of the State board or other control, or else by contract with private parties, establish an efficient forest cover. The State can command the necessary funds probably at 5 or 6 per cent, while the private individual must pay from 10 to 20 per cent; the State engaged in this enterprise on a large scale, can also do the planting, etc., more cheaply and more efficiently.

After 10 or 15 years, when the plantations have become self-supporting and begin to yield valuable material, the former owner of the land or his successor may be given opportunity of reclaiming his property by repaying price received for the land with interest and cost of plantation less share of the taxes paid toward the forest improvement fund; submitting, however, in the use of the forest growth to such regulations as seem necessary to insure continued value as a cover.

By some such plan, in which I can not see anything impracticable, the advantages of coöperation and State credit are secured, and yet those who are directly benefited have paid for it; at the lowest rate, however.

What I have seen of the enterprising spirit in your State, and especially what I have heard of the management of your board this afternoon, has inspired me with the belief that it is not chimerical to expect action of this kind from your public spirit.

IV. EXPERIENCES IN TREE PLANTING ON DAKOTA PLAINS.

[The two communications which are here appended were received from two correspondents of the division, who have had some experience in tree planting on the prairies of Dakota. While it will be found that some of their statements and deductions are not, at least in their general application, in harmony with the preceding representations, they are nevertheless given in full just as they were written, and will be found interesting as giving brief and, on the whole, safe detailed directions which may well supplement the preceding general considerations.]

1. TREE CULTURE ON THE WESTERN PLAINS.

By A. M. THOMSON.

I am asked to give the results of my observation and experience in tree culture during a residence of 6 years in North Dakota. I assume that what the Department wants is such knowledge of practical experiments made on the ground as will aid the settler on these wind-swept prairies in starting and maintaining a grove of trees that will afford him protection in winter, and ultimately fuel and timber for domestic purposes.

While scientific men are seeking for the causes that prevented the natural growth of timber on the barren plains of the West, the hardy pioneer who has gone there with his family to stay and to help on the development of the country and the stability of the Government by making a home is much more interested in the important question, "How can I raise trees to supply my wants?" Any man who can state a single fact which will throw a ray of light on the general subject will confer a lasting benefit upon tens of thousands of farmers beyond the Mississippi River who have been trying for years to solve this problem without any satisfactory results thus far.

THE TREE-CULTURE LAW.

It is an open secret that the tree-culture act, now repealed, has almost totally failed to meet the expectations of its authors; that not one claimant in a hundred in the two Dakotas, and the remark will hold good equally well when applied to other Western States, has ever succeeded in raising trees, and that it has simply been made the convenient and lawful cover for speculation in government lands by both residents and nonresidents. Both the law and the speculator were to blame for this result.

The Government offered the settler 160 acres of land for doing precisely what any thrifty man on the prairies would naturally do on his own motion, though perhaps on a smaller scale, the cultivation of a grove of trees for shade, shelter, ornament, and use; but the defects of the law are so numerous that the liberality and good intentions of Congress have utterly failed to accomplish any good result.

Only one quarter section can be entered as a tree claim on each section, leaving the three other settlers on the three remaining quarters without any chance to be benefited by the law and having no stimulus to raise trees beyond what their own necessities suggest. The first man at the land office gets the chance of the Government's liberal offer, and those who come after him get nothing. It would have been infinitely better for all concerned if the Congressional gift had been smaller in size and extended in some way to every man who settled on the public domain. To properly plant and cultivate 10 acres of trees has been found to be an undertaking that has cost the farmer more than any other method yet invented to acquire 160 acres of Government land. The reasons will appear further along in this paper. The number of acres ought to be limited to 5 and the farmer ought to have been allowed to start his trees in the nursery, and cultivate them there until 2 or 3 years old before setting them out in the grove, and the time that they were growing in the nursery ought to have been allowed to count the same as if grown on the claim. No non-resident ought to be allowed to enter a tree claim. He has used it in this way: A, in Ohio or Vermont, enters a tree claim in North Dakota. He breaks 5 acres the first year, according to law, crops it the second, but does not plant it the third, because in the 2 years that he has had a filing upon it, it has advanced so rapidly in price that B, of New York or Indiana, offers him a round sum for his relinquishment, and he accordingly relinquishes his right to the claim and B files upon it. B does not begin where A left off, but treats the entry as an original purchase and has 8 years in which to break, sow, plant, and raise trees, the same as if A had never seen it. At the end of 2 years B finds himself with the same opportunity for selling out that A struck, and he sells out to C, and he obtains possession by the purchase of B's relinquishment. Four years have already elapsed since the first entry was made by A and not a seed has been planted. Nor was it the intention of either A or B to raise trees at any time. They dickered in the land for the sole purpose of gain, and they merely took advantage of the loopholes in the law.

Those who unfortunately can not sell their claims before they are required by law to plant with seeds, cuttings, or trees adopt the shortest and cheapest method of complying with the letter of the law without regard to its spirit. One man came to me in November to borrow money and offered the relinquishment of his tree claim as security for the loan. When asked if he had strictly complied with the requirements of the law as to tree claims he said he had; that he had plowed 5 acres the first year, cultivated a crop upon it the second year, and had planted it with seeds the third. Being questioned more closely he admitted that the tree seeds were sowed broadcast with an oat crop and that he had not seen the land since the oats were harvested. He did not know whether there was a tree on his claim or not, but he had planted 5 acres of seeds as the law required, and could no doubt have obtained witnesses of the fact of other tree claimants around him who had dodged the law themselves in a similar manner. A large majority of the settlers in some localities are in the same boat, and they stand by each other. They are not intending to raise trees, but to hold the land until they can sell out to advantage. Many of the first filings on tree claims are sold to newcomers, who enter them as homesteads or preëmptions.

In Dakota, before the admission of the two States, the Territorial legislature made an honest effort to supplement the act of Congress to encourage the growing of trees, and passed a law exempting from taxation $1,000 worth of property from the assessment of any farmer who would plant and cultivate a certain amount of ground in trees on his homestead. Some settlers have availed themselves of the privileges of the law, and in the course of time it may stimulate landowners generally to plant trees.

The man who removes from any of the Eastern States or Canada to the treeless plains of Dakota and imagines that it is an easy matter to raise trees will be very much disappointed and perhaps disheartened before he cuts his own firewood or fences his fields with posts grown under his own eye. Nothing turns out as he anticipates. His experience in Ohio, Pennsylvania, or Wisconsin goes for naught. There is something in the soil or in the climate or in both combined that seems adverse to tree culture, and his earlier efforts only convince him that there is "no excellence without great labor." The same care and industry that produce a grove of trees in Illinois or Iowa 20 feet high in 10 years will often do very little towards that result in Dakota. One old squatter once said to the writer that "tryin' to raise trees on these prairies is agin natur," and added that "if natur intended trees to grow here they would have been here before the country was settled." The answer was made that the same might be said with equal truth as to the growing of wheat.

My first attempt at tree-raising was on a piece of ground that had produced two crops of wheat, and it was prepared by a thorough plowing 8 inches deep. Then it was marked out 4 feet apart each way with a corn-marker and planted with box elder tree seeds, the work being done about the middle of October. I had no experience in the business, neither had my neighbors, so I struck out by guess and planted the seeds 2 inches deep, or about the depth that corn is usually planted. This was my first mistake, and it is sufficient to say that I never saw the sign of a tree on the 3 acres thus planted. I suspect that poor seed had something to do with it, but subsequent experiments convinced me that very few tree seeds of any kind will germinate if buried at a depth of 2 inches. In the woods, of the very few seeds that sprout of the millions that fall to the ground each season, they get but a very slight covering, consisting of a few wet leaves or a little dust blown over them by the wind. My only success has been with the slightest covering that it was possible to make. One planting that I made I instructed the men to use no hoes, but simply cover the seeds with a little dirt drawn over them with the foot. They were instructed to cover as shallow as possible, and on the ground thus planted I had the best stand of trees. So far as seeds are concerned their use is undoubtedly the cheapest for the farmer on the start in helping him to keep within the requirements of the law, but with the general average of people I incline most decidedly to the opinion that cuttings or small trees are the best and most economical in the long run.

It is still a dispute concerning the length of time that tree seeds will retain their vitality, but I would not plant seeds that were more than a year old. By far the safest way is to gather the seeds as soon as ripe and plant them at once, or at least before the ground freezes. Large amounts of box elder and white ash seeds, the two most common varieties that are used on tree claims in the two Dakotas, have been sold to planters after having been kicked about the nurseries and seed stores for years; and to this cause alone many failures may fairly be attributed.

Here, for example, is a man who has put off planting until the last moment; he must plant at once or his claim is liable to be contested on account of his failing to comply with the law, so he buys the first seeds he can lay his hands on, summons his neighbors, and plants his 5 acres of trees. He may know or suspect that the seeds are worthless and that he is throwing away his work, but he is complying with the law (apparently), and his neighbors who help him do the planting are all ready to swear that they are witnesses of the fact and aided in doing the work. He may never see a tree, but his claim is safe from the grasp of those who are land hungry, and he can get the time extended "on account of the drought," or any other alleged misfortune.

If the planter will take proper care of his young trees and cultivate them as he ought the use of seeds is undoubtedly the best plan, as the loss of about 1 year in their growth from transplanting is obviated; but the ordinary farmer usually has his hands so full of other work which can not be postponed that the trees are neglected and are smothered with weeds. If seeds are used the question arises whether it is as safe to purchase those grown in another State and in a different climate as those raised at home? My own failures have been with seeds that were purchased of the dealers, and my success has been with those picked at Devil's Lake by my own men. Seeds raised in the same region where they are to be planted are most assuredly the safest and best. If the law would permit it, the best way to proceed with a tree claim would be to plant the seeds in nursery rows and cultivate them properly until of sufficient age and size to transplant. The planter would gain at both ends by this plan; first, his trees would be getting a good start while his land is being subdued from its wild state to become a suitable habitation for so fine and beautiful a thing as a graceful tree. There is something almost pathetic in the disappointment of the Eastern man who digs holes in the tough prairie sod and plants a few shade trees in front of his Dakota sod shanty, hoping that they will grow as they do "back home" and afford a fine shade in the "sweet bye and bye" when prosperity has enabled the hopeful farmer to build a new house. They may put forth leaves in May, but are sure to die in August.

My second attempt was with 5 acres of wheat stubble thoroughly plowed and dragged and planted 4 feet each way with seeds, mostly white ash and box elder. The planting was done late in the fall, and in the spring I had the satisfaction of seeing as fine a stand of trees as one could wish. During the summer they were cultivated both ways twice and hoed once. The field was kept as clean as a field of corn, and in fact the trees were treated the same as is usually accorded to corn or potatoes. The planting was on the open prairie and exposed to the fierce winds from all quarters of the compass. The fall of snow that winter (1886–'87) was very slight in that section and in the spring I found that thousands of my young ash trees had been winterkilled. This surprised me very much, as the white ash is considered perfectly hardy even in the hyperborean climate of Dakota, and the seeds for my planting had been gathered at Devil's Lake, as above stated. Here was another revelation. The box elder had also suffered, but not so badly as the ash. What was the matter? The previous summer had been quite dry and the growth of wood had been short, but that I supposed to be favorable to ripening the wood and preventing winterkilling. Then I asked myself the important question: If the season of growth in Dakota is too short to sufficiently ripen the wood of the ash so that it will withstand the winters, how are trees ever to be grown successfully in this climate? It was a question without an answer. And yet there was a partial solution.

I had seen large ash trees at Fort Totten and along the banks of the Cheyenne River, but always in sheltered positions. Under the bluffs along the banks of the Cheyenne many varieties of native trees can be found of considerable size, while only 12 miles away along the banks of the James River, whose course is through the almost level prairie for many miles, there is not the sign of a tree of any kind, not even the burr oak, which puts in an appearance and holds its own wherever there is a chance. Then I found that some of my trees that were sheltered on the north and west by a weed that had made a snow bank had not been killed. Some small trees that had grown under the lee of larger ones on the north had escaped while the larger ones were dead. One of my neighbors had a planting of white willows and box elders 4 years old, the rows running east and west. The willows had been allowed to grow quite bushy, and so thick as to present considerable of a wind-break. I noticed that only two or three of these bushes on the west end of the rows were dead; the others, having the advantage of the shelter afforded by these outposts, were green to the very tips of the smallest boughs. Another man had planted corn among his trees and let it stand all winter as a protection to his trees with good results. His opinion is that as soon as groves of forest trees are sufficiently grown to afford shelter, apple trees of the hardy varieties may be successfully cultivated in all parts of Dakota. Others are hoeing about their trees, but letting the weeds grow between the hills to help protect them in winter. If some sort of shelter is needed for young trees in winter—and it seems to be imperative—the importance of first planting one's trees in the compact nursery rows so that they can be protected by a board fence, or a barricade of manure on the west and north such as I have often used, can not be overestimated. The settler could plant his nursery on the start so that his trees would be ready for planting by the time the ground was fully prepared.

VARIETIES.

The average settler who has been reared where natural forests abound knows as little concerning the best trees to plant on the plains as he does of many other facts connected with the business. If he takes the unsolicited advice of those who have trees to sell that have been grown in some distant State he runs a risk of spending his money for nothing, and will meet with disappointment in the end. Many kinds of trees that are indigenous in northern Iowa, Wisconsin, and Illinois, and are even hardy in those latitudes, have been found too tender for Dakota unless in some sheltered position where the case is so exceptional that the example is not of universal application. What the western farmer wants at first is two or three sorts that are perfectly hardy, if any such there be, and stick to them until he gets a good start. Hardiness, rapid growth, and utility are the three most important characteristics that should govern him in makand his selection for field planting, leaving the nurserymen and the experiment stations to make tests with different varieties. As far as my observation extends, and it is corroborated by the experience of many others, the three varieties that have succeeded best on the prairies, under all circumstances, are the box elder, cottonwood, and white willow. White ash does well and is a more valuable wood when grown than either of the others, but it is of too slow growth to meet the requirements of this go-ahead generation. I have tried black walnut, basswood, burr oak, wild cherry, hard and soft maple, yellow locust, chestnut, and others, only to be disappointed in the result. The black walnuts grew luxuriantly the first year and were the admiration of all beholders, but alas, the second year they did not respond to the invigorating touch of the south wind and the genial May sunshine. They were well named black walnuts. Dead as a doornail. Hard maple I dismissed because of its too slow growth, and its half brother, the soft maple, had to be abandoned because it is too tender unless protected. I have still strong hopes of it after thorough acclimation, because its rapidity of growth, which is the chief objection to it in Illinois and Wisconsin, makes it a most desirable variety, besides being so easily propagated. The yellow locust that has been raised so extensively in many of the Middle States, and which is so valuable for fence posts, had to be given up with great reluctance after a thorough (?) trial.

I now confine myself exclusively to box elder, white willow, cottonwood, and white ash, and have a fine stand of each of these varieties. In my opinion the box elder has little to recommend it except its hardiness, for I have seldom seen a straight, graceful tree of that species in any country, and why they are planted in latitudes where the maples and elms are easily cultivated is a mystery. But on the western plains they flourish where most others fail, and it is vastly better than nothing. The cottonwood, with which the Northern Pacific Railroad Company has been most successful in securing a growth for hundreds of miles along its road to defend its line against snowdrifts that fill its cuts, is a rapid grower and a handsome tree when young, but an unsightly thing in its old age. The white willow bids fair to become a general favorite because of its rapid growth and its perfect hardiness, more danger to it being apprehended from summer drought than from winterkilling.

PREPARATION OF THE SOIL.

In regard to the preparation of the soil, that has been pretty much settled by the terms of the Congressional act relating to tree claims, but I am by no means certain that the course therein marked out is the best. The law is imperative that the first 5 acres shall be planted the third year after filing, while some farmers are of the opinion that it is better to plant as soon as the land can be properly prepared after breaking. My own personal experience leads me to coincide with this view, as the best stand of trees on my own place was treated in that way. The land had been broken in the spring and was planted with potatoes, the seed being dropped in the furrows after the breaking plow, a method often adopted by lazy farmers on the frontier. After the potatoes had been dug in the fall the land was plowed or "backset," and marked out with the plow 4 feet apart one way. Into these furrows box-elder seeds were sown and a little dirt scratched over them with a garden rake. I called it the most slovenly job I had ever done in Dakota, but the trees from that planting have flourished better than any others on the place, and I am not sure but the newer the ground, if it is fit, the better. Of course the trees were hoed and kept clear of weeds every year. The trees have defied summer's drought and winter's cold, and are now large enough to take care of themselves. I may add that the seeds thus carelessly planted were what remained after planting 5 acres on well-pulverized ground where no tree is to be seen to-day, so that the failure on the old ground can not be attributed to poor seed.

A DISCOURAGING BUSINESS.

From the above brief and imperfect presentation of the subject it will readily be inferred that tree culture on the western prairies is a very discouraging undertaking and one that has no poetry at all in it. The great obstacles in the way of success are the natural perversity of the soil and climate; the dry, hot summers; the intense, cold winters; the windstorms; the late frosts in the spring that cut down the young trees; the early frosts in the fall that prevent the sufficient ripening of the wood; the cutworms; poor seed; worthless varieties of trees; and last, but not least, neglect on the part of the owner. And yet, notwithstanding all these obstacles—and I appreciate their force to the fullest extent—I declare my belief that the time will come when these vast treeless areas will be ornamented with fine groves of timber that will shade the farmhouse from the burning rays of the summer's sun and afford shelter from the fierce blizzards of the pitiless winters.

2. FOREST-TREE CULTURE IN DAKOTA.

By J. W. Smith.

In giving my experience in tree-culture, after planting 60,000 trees in Central Dakota within the past 6 years, I will try to be brief and practical, dividing the subject as follows:

First. Selection and preparation of soil.

Second. Kinds of trees; how and where to plant; trees or seeds.

Third. Aftercare and culture.

Fourth. Errors of the past; the teachings of experience, and suggestions for the future.

Almost any soil will produce trees under favorable circumstances, but soils differ greatly and the proper preparation of any soil is essential to success. Deep cultivation and the total destruction of the prairie grasses and weeds is also necessary to secure the best results. An Iowa cultivator of evergreens once remarked to me that "only time and thorough tillage could get the rawness out of new prairie soil so that evergreens would thrive." This truth doubtless also applies to most deciduous trees. Thorough and deep preliminary cultivation, then, are essential to successful tree-growing on the prairies.

The kinds of trees to be selected must vary with the climate, soil, locality, etc., experience being the only sure guide. Native trees growing near in similar soil can hardly fail. Beyond that, where possible, it is best to be guided largely by the experience of others. White and green ash, water or white elm, and box elder seem about equally hardy. Cottonwood and white willow are not hardy except in moist soils, each usually failing after a few years' growth. A limited experience with some other willows and several poplars leads me to think some of these may prove more hardy. The larch, basswood, wild black cherry, native white birch, and some other trees, mostly American, promise well in places, and deserve further trial. Soft maple does not seem very hardy. It may, like some other kinds, be more hardy when older and where protected by other trees. The nut-bearing trees, black walnut excepted, and that grown from seed, killed wholly the first winter. Only a few evergreens have been tested. Small red cedars have been partially killed at times, not always, and never entirely. Few others appear as hardy. White pine may be, and grows faster.

Trees should always be planted in spring, summer, or autumn, according to kind. I have usually planted trees of 1 to 2 years' growth; think 1 year preferable, and with few exceptions prefer them to seed, if in good condition. Some good cultivators prefer planting seed, and if it germinates well, the great difficulty in dry soil, it is preferable to trees, as the roots of trees must be more or less injured in digging, handling, and transplanting. Small trees can be planted very rapidly with a spade, if the ground is marked, or by a hoe in a plowed furrow. Mr. R. Douglas, of Waukegan, Illinois, gives admirable instructions for planting upon a large scale. The essential things with any method are (1) to have the ground properly prepared; (2) to have good trees or seeds; (3) to have the work well done at the proper time; and (4) to have the trees well cultivated and protected in after years. It is preferable to have some trees watered and even mulched when planted, though with small trees this is not usually necessary.

The after care and culture is as important as proper planting. If 4 by 4 feet distant and in rows each way, the most common method, they can be cultivated like corn, and the kind of culture they receive will be as visible by their growith, condition, and even the life of some of them in after years, as it is upon a crop of corn. If the land was deeply plowed and cleanly cultivated for several years before planting the trees will not be likely to suffer from drought unless their culture is neglected.

Frequent shallow cultivation of the whole surface soil, while destroying weeds, will also prevent the injurious effects of excessive dryness. Cultivation should cease by about August 1, to prevent too late growth and consequent winter killing. After that date all large weeds and any near to a small tree should be removed by hand work. Only clean culture for several years and protection of the tree from the tramping and browsing of live stock will secure healthy and rapidly growing trees. Prairie fires are dangerous if the land is very weedy, or if the trees are so large that cultivation has ceased. To be safe, a sufficient breadth of land should continue to be cleanly cultivated, it may be with some suitable crop.

The growth of trees is variable, owing to many causes, as soil, season, cultivation, etc. Cottonwood, where hardy, grows faster than most trees. All the ashes are slow growers. In 8 years the average growth of cottonwood is 6 inches in diameter, of soft maple and box elder 4 inches, and of ash not over 2 inches. If pruned or thickly planted, trees grow taller than where growing more scattered or singly, nature always adapting the shape of trees to their surroundings.

Some woods being so much more valuable than others, it is wise to try the cultivation of the more desirable kinds and to increase the planting of such as fast as found to succeed. When a wind-break is of the first importance it is best to plant for that object mostly rapid-growing kinds; elsewhere chiefly those of more value for fuel, fencing, building, and lumber. Some of the oaks are hardy and should be early planted, the acorns being preferable to trees.

Among the common errors of the past have been the hasty and imperfect manner in which prairie tree-planting has been done—preparation of the soil, quality of trees or seeds, and the neglect of proper care. The "tree-claim" or timber-culture act is partly responsible for many of the failures under its requirements. Thus it specifies that the prairie must be "broken" one season; the next year it must be cultivated with or as for a crop; and the third year it must be planted with trees or seeds of forest trees, the usual result being that the land was not sufficiently cultivated to secure a good growth of trees by the proper cultivation in future years, it being nearly impossible to remedy what was lacking by ordinary cultivation, so that many trees are dwarfed or lost by weeds or drought.

It is also to be feared that quite a proportion of those who entered "tree claims" thought more of complying with the letter of the law, to obtain the land, than with the spirit of it, to secure a good growth of trees. To even look at some claims is sufficient proof that something is wrong. After a few years such parties are frequently glad to sell their claims, often without trees, for a trifle. If reëntered as a tree claim it was often by an inexperienced party, who in a few years was also glad to "relinquish" or give away his or her claim to some other party, and who, if experienced, will often enter the land as a preëmption or homestead. Such is the history of hundreds if not thousands of tree claims, and it will continue to be until the act is amended or repealed. Happily, in contrast with those described, some model tree claims can be found in nearly every county.

The writer respectfully suggests that if the preëmption and tree-claim acts are to be repealed, as now appears likely, the tree-claim act in some modified form should be ingrafted upon the homestead law, so as to require at least 5 acres of timber trees to be successfully cultivated upon each 160-acre homestead in future, but requiring two crops where one now, and thorough cultivation before planting trees or seeds.

Five acres of forest trees upon a homestead is only a reasonable requirement. It would also soon greatly modify the climate of the prairies; could be made valuable as a wind-break about the farm residence and other buildings; could afford desirable shelter belts for live stock at different places on the farm; in a few years would furnish considerable fuel, fencing and building material, besides adding wealth and comfort to the owner, health to the community, and beauty to the landscape.

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